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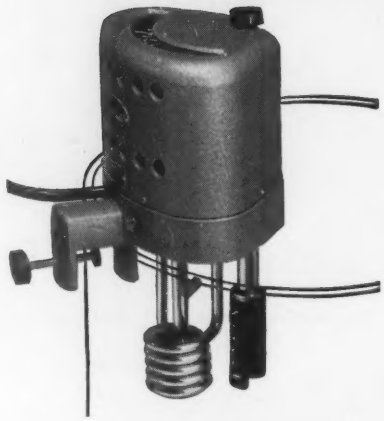

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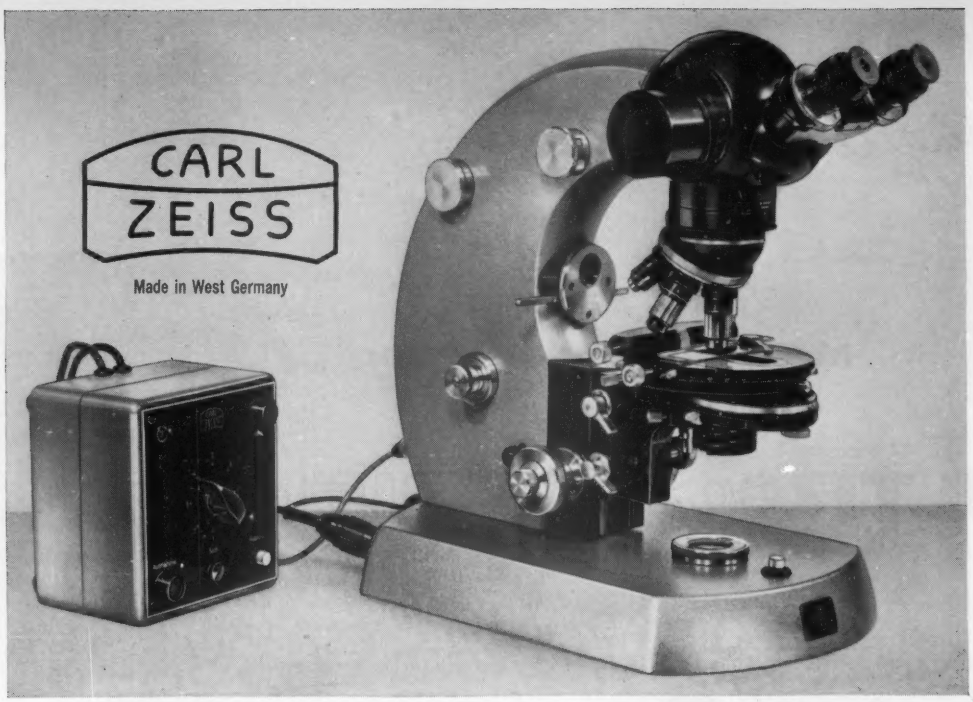

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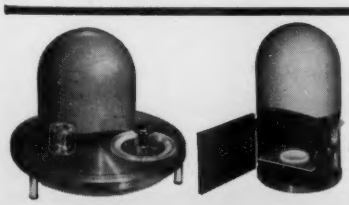

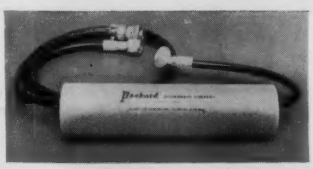

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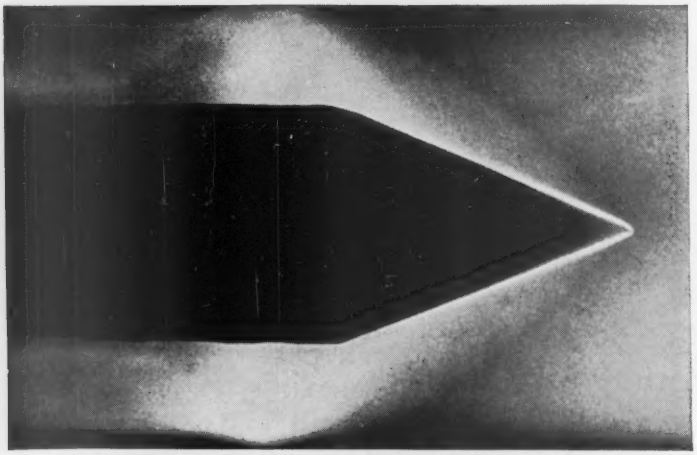
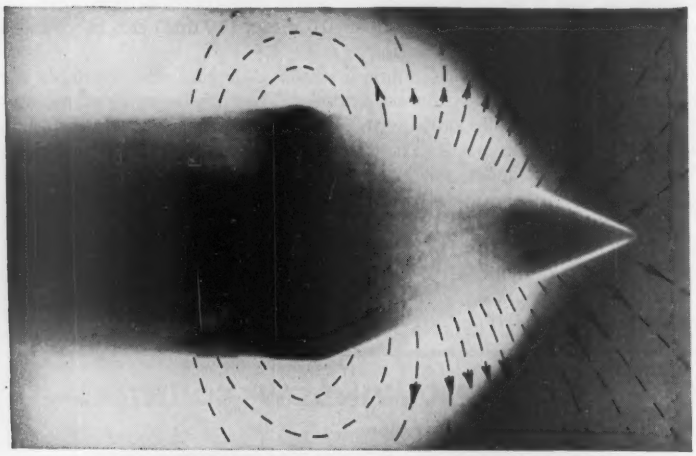


NO MAGNETIC FIELD. This shock tube photograph, taken by emitted light only, shows the typical shock wave configuration formed by high-velocity gas flowing around a pointed cone.



WITH MAGNETIC FIELD. Here is shown the magnetohydrodynamic displacement of the shock wave. The magnetic field is caused by electric current flowing through a coil of wire within the cone. This experiment qualitatively demonstrates the interaction of a high-temperature gas with a magnetic field. This effect would be expected to produce drag and reduce heat transfer to the body.

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Arthur Kantrowitz

Dr. Arthur Kantrowitz, Director
Avco Research Laboratory

P. S. A listing of laboratory research reports indicative of the scope and depth of our activities is available. Address your request: *Attention: Librarian, Avco Research Laboratory, 2385 Revere Beach Parkway, Everett, Massachusetts.*

*Magnetohydrodynamics, the study of the dynamics of electrically conducting fluids interacting with magnetic fields.

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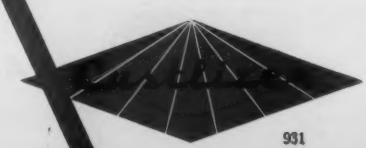

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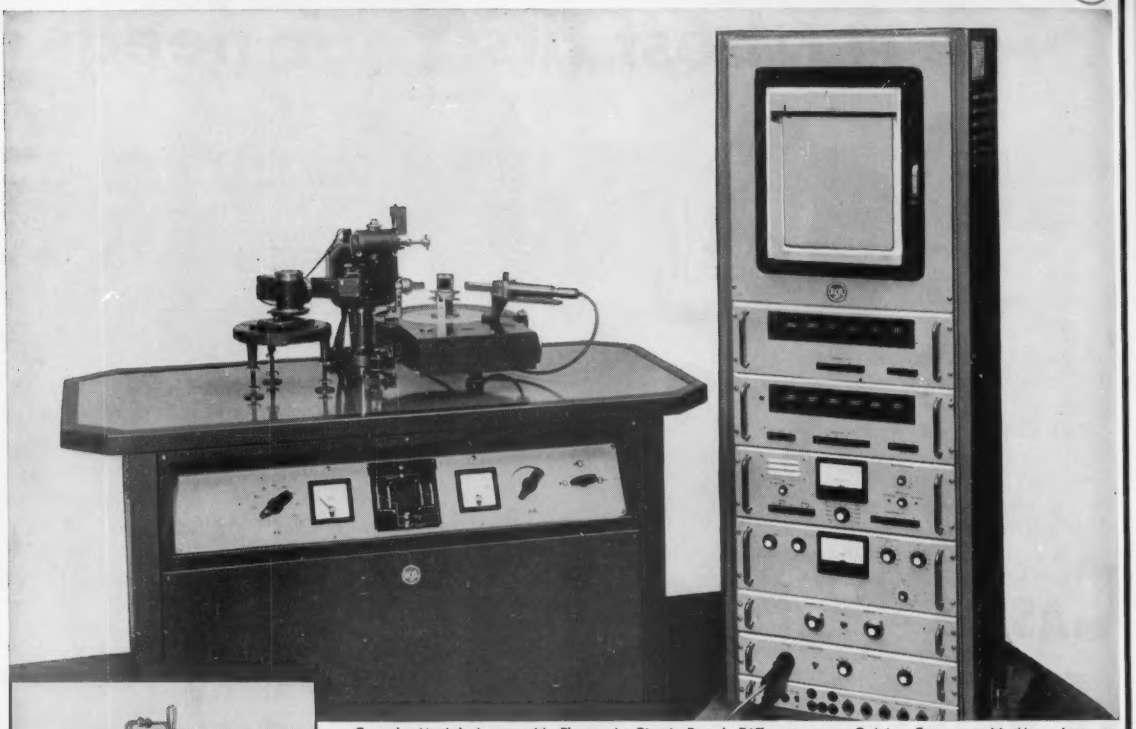

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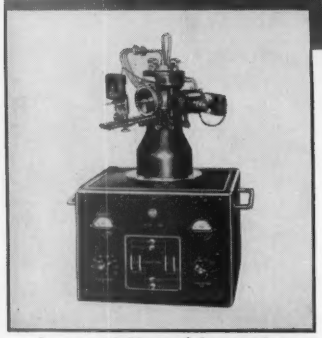

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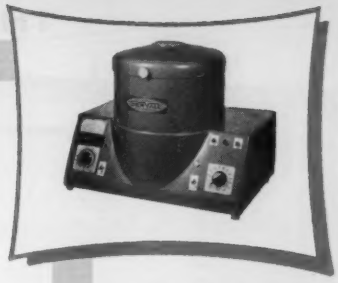

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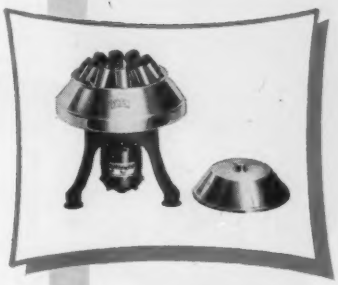

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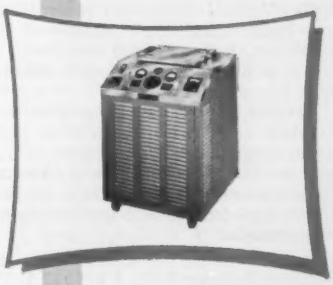

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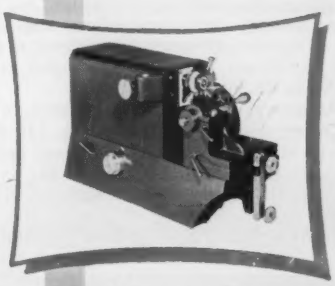

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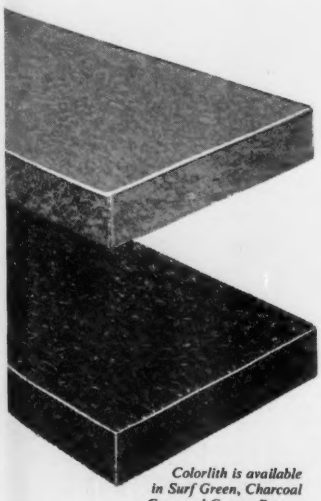

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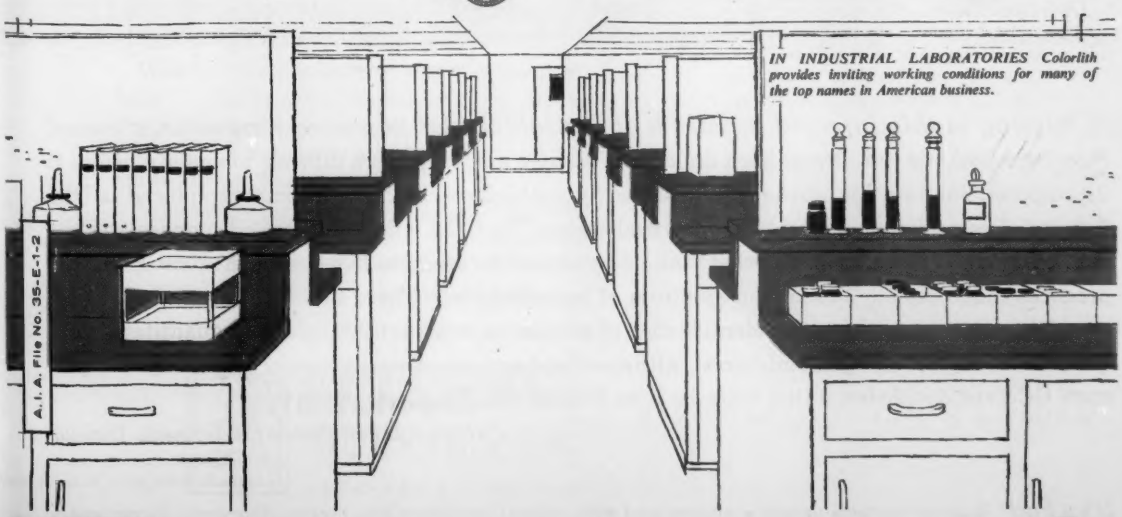

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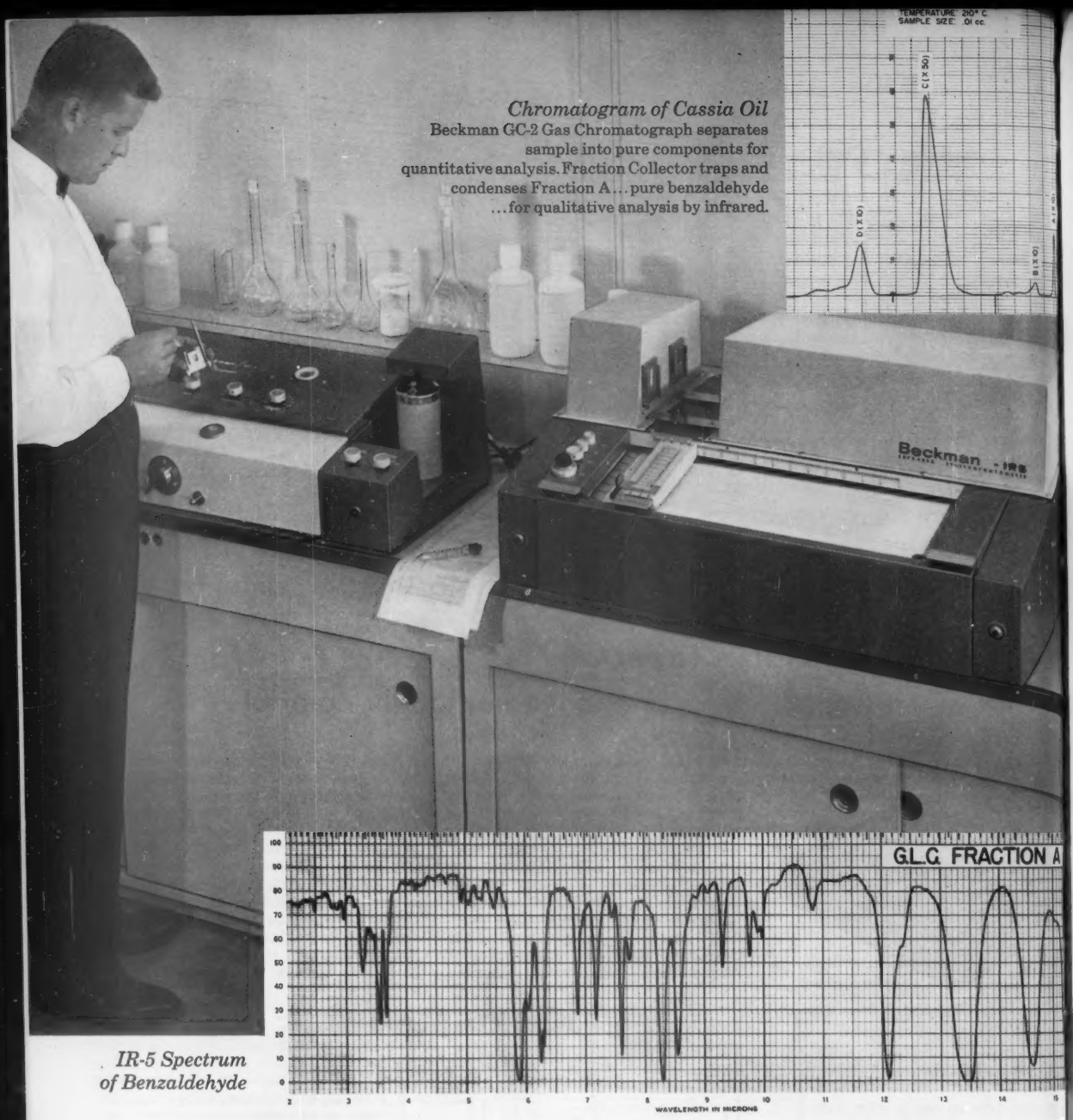

Chromatogram of Cassia Oil
Beckman GC-2 Gas Chromatograph separates sample into pure components for quantitative analysis. Fraction Collector traps and condenses Fraction A... pure benzaldehyde ...for qualitative analysis by infrared.

IR-5 Spectrum of Benzaldehyde

What's missing in this Infrared Spectrum of Benzaldehyde? Benzoic acid impurities, of course! Pure benzaldehyde has always been difficult to prepare and even more difficult to analyze before it decomposes. But now, this problem can be solved by combining a GC-2 Gas Chromatograph and an IR-5 Infrared Spectrophotometer into one analytical system. The GC-2, with Fraction Collector, isolates the pure fraction which is then transferred to an IR-5 microcell for analysis. In just sixteen minutes the IR-5 produces this complete 2-16 micron spectrum of benzaldehyde. ⌘ These Beckman instruments allow complete separation and positive identification of samples as small as 0.0002 cc...both quantitative and qualitative analyses of organic mixtures...with speed and accuracy. To learn more about the high-temperature GC-2 and double-beam IR-5, write for Data File L-52-38.

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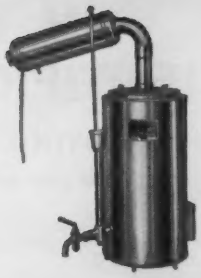

Typical Laboratory Still: Electric heated. ½ to 10 gallons per hour capacity.

½ to 500 gallons per hour

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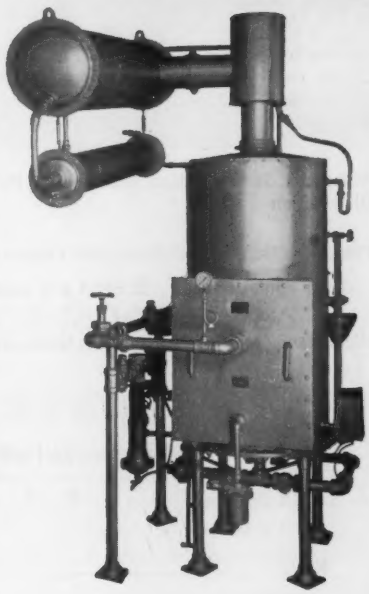

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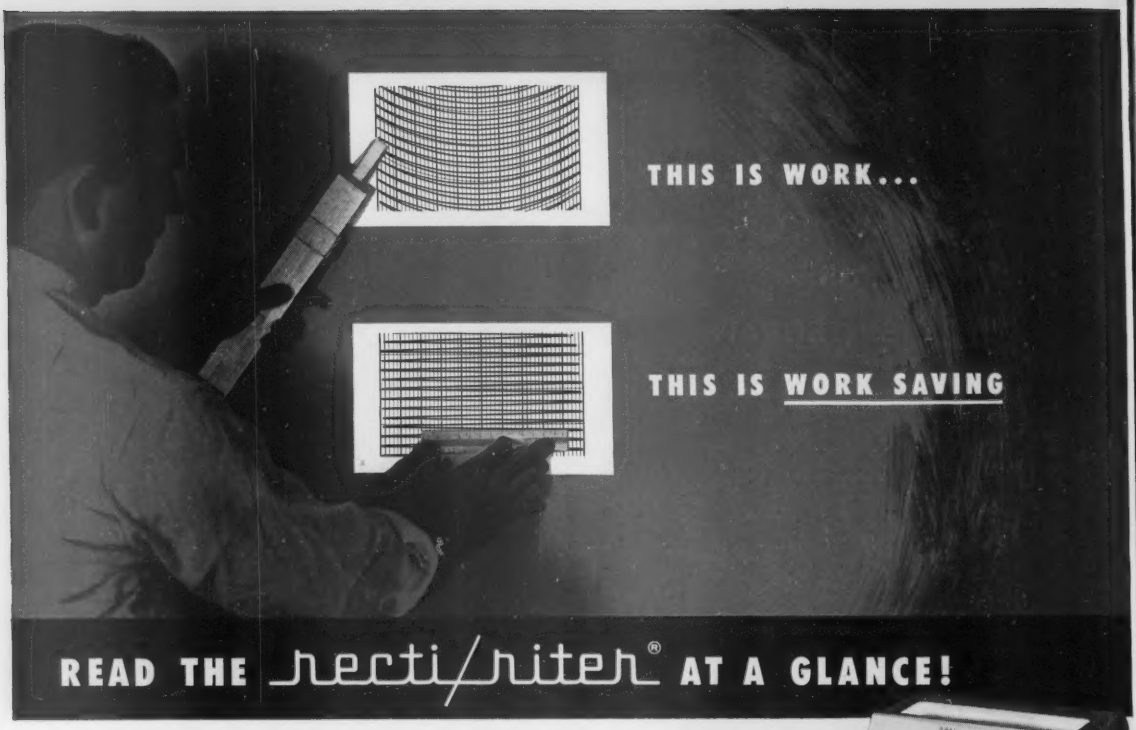

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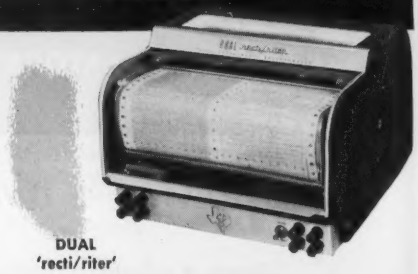
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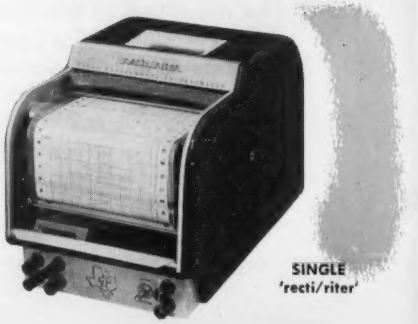
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Henri Bergson...on making gods

Humanity is groaning, half-crushed under the weight of the progress it has made. Men do not sufficiently realize that their future depends on themselves. They must first decide whether they wish to continue to live. They must then ask whether they want merely to live, or to make the further effort necessary to fulfill, even on our unmanageable planet, the essential function of the universe, which is a machine for making gods.

Les deux sources de la morale et de la religion, 1932

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A nonprofit organization engaged in research on problems related to national security and the public interest

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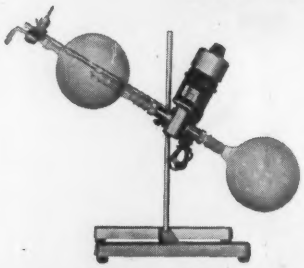

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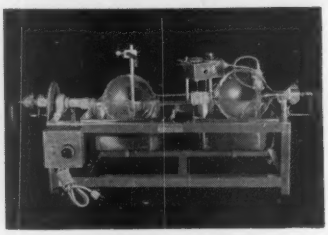
Bulletin FP-2D



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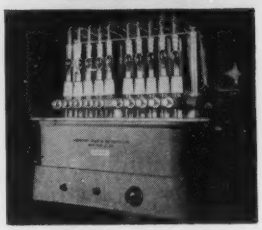
Standard equipment in most laboratories. Preferred for permanent installations and for heavy duty operation, but with all basic features of Portable Model. For continuous or batch operation, with easy conversion from one to the other.

Bulletin FE-2D

EVAPO-MIX



For evaporation of fraction cuts directly from test-tubes. Evaporates water at rate of 1.0 ml/min; ethanol, 4.2 ml/min; ethyl acetate, 7.2 ml/min; and acetone, 10.0 ml/min. Simultaneously evaporates 10 test-tubes, 16-20 mm dia. x 150 mm long. Connects to water aspirator for vacuum. Automatic thermoregulator controls temperature from room to 200° C. Controlled vibration prevents "bumping" during heating. Closed system of glass and inert plastic prevents contamination.

Bulletin 3D-2000

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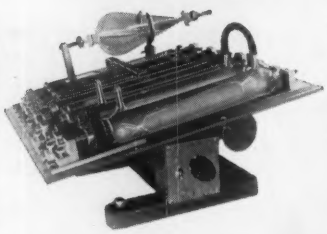
OMNI-SHAKER



A sturdy all-purpose variable speed shaker designed for the laboratory bench, cold-room, or refrigerator. The only available unit for shaking stoppered test-tubes and vessels under pressure. Ideal for equilibrium dialysis, continuous-flow dialysis, and micro and thin-layer dialysis. Furnished with explosion-proof motor, if desired.

Bulletin 2D-3000

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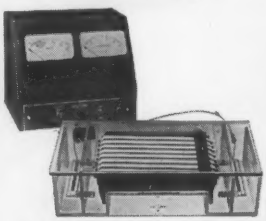

Completely furnished with all accessories for either paper strips or starch blocks. Power supply designed specifically for electrophoresis. Suitable for research, routine clinical output, or large scale separations. Compartmented starch tray interchangeable with paper carrier in migration cell.

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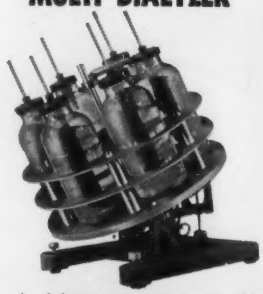

A laboratory apparatus for rapid mechanical dialysis of multiple samples against different buffers. Sample volume one to 4,000 ml. Complete dialysis in less than two hours for most applications assured by agitation of both buffer and sample. Accessories available for continuous-flow dialysis.

Bulletin 2D-1000

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- Nomograph give chloride concentration *without calculating*
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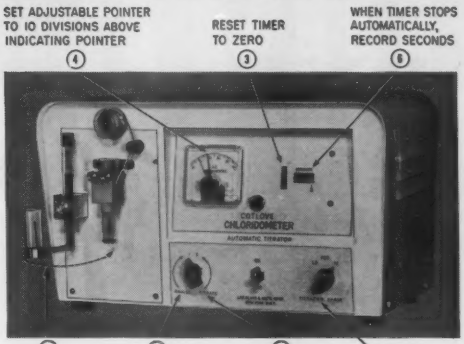

ACCURACY: ± .5%, better than ± .1% under optimal conditions.

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PRICE: Complete as shown and ready for operation with 1 set of silver electrode, 1 oz. silver wire, 2 stainless steel vial rack, 3 vials powdered gelatin reagent, polyethylene spray bottle, cleaning kit, instrument cover, instruction book and Chlorograph ..... **$498.**

*Designed by E. Cotlove, H. V. Trantham and R. L. Bowman, National Heart Institute, Bethesda, Maryland.

For information write for Bulletin 4-2000

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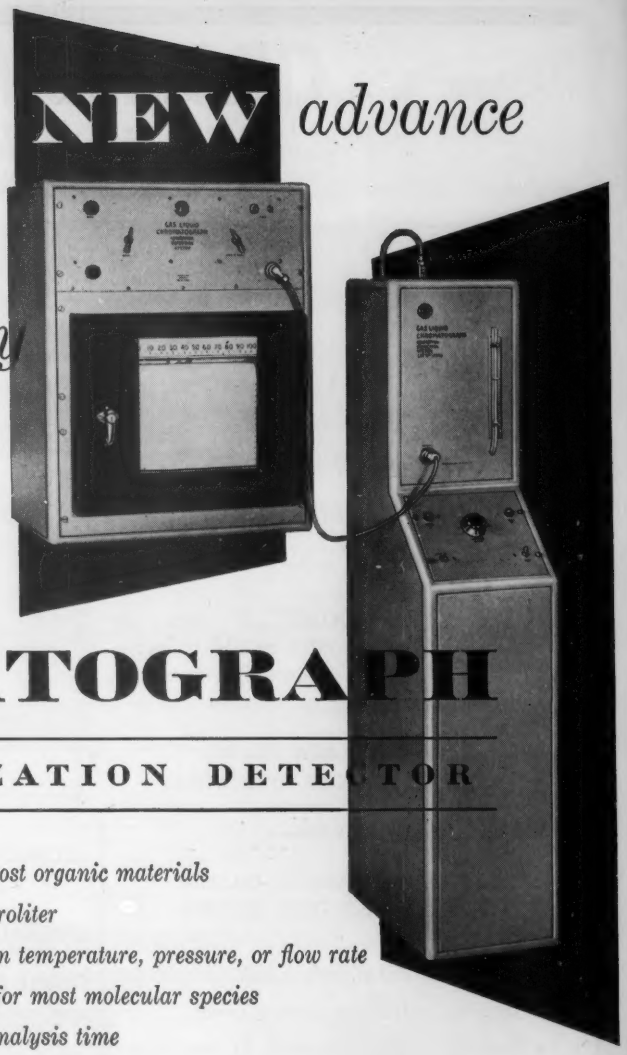
A spectacular **NEW** *advance in gas-liquid chromatography*



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★ *Accepts samples as small as 0.025 microliter*

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Million Plus*

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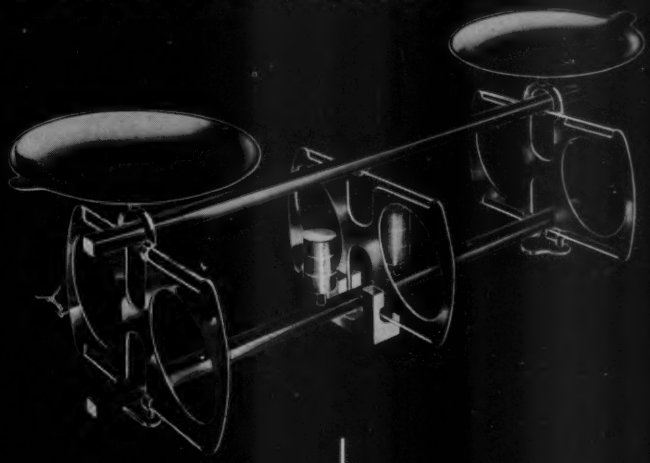

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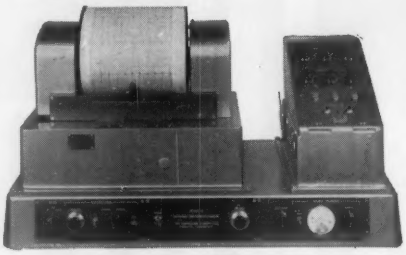
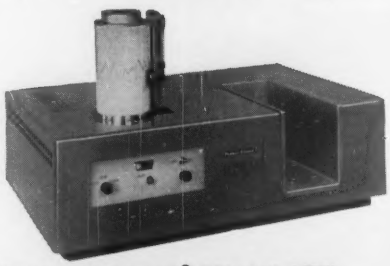
The Model 21
double beam recording infrared spectrophotometer

Leader in the infrared field, the Model 21 offers complete flexibility in spectral presentation, speed and resolution. Wavelength range from 800 millimicrons to 35 microns. New Model 321 available with double beam, double pass system.



P-E Analytical Instruments

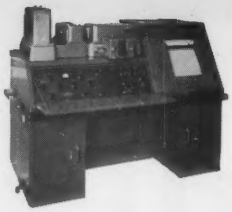


The Infracord® Model 137
double beam recording spectrophotometer

New low-cost infrared instrument for organic chemist and spectroscopist. Fast scan (2.5 – 15μ in 12 minutes), atmospheric and solvent compensation, differential analysis, instant wavelength reset, and linear wavelength vs transmittance recording. Records on notebook size paper. Handles spectroscopist's routine work.

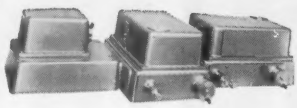
Building Blocks and Accessories

Sources, monochromators, detectors with associated optics, electronics and control systems which may be assembled in many combinations. Covers infrared, visible and ultraviolet emission ranges completely.



The Model 13U
universal spectrophotometer

High performance in ultraviolet, visible, near IR and fundamental IR regions. Operates as a double beam, ratio recording or single beam instrument. Accommodates IR microscope.



The Model 112G
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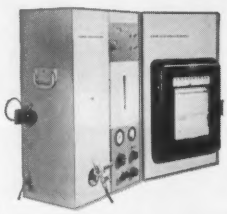
A very high resolution instrument with high energy per spectral slit width. Single beam, double pass operation. Less than 0.1% scattered light.



The Model 154C
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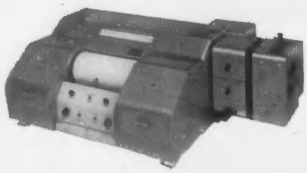
A low-cost, vapor phase chromatography instrument capable of handling a wide range and high volume of chromatographic problems. Analyzes gases and liquids boiling up to 300°C. Available with reproducible gas and liquid sampling systems, fraction collection systems, integrators and a wide variety of column materials and sizes.

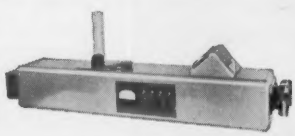


Spectracord® Model 4000
recording ultraviolet spectrophotometer

Features a double monochromator for high resolution and low scattered light (max. of 0.01% between 222 Mμ and 1.5μ). Covers visual, near IR and ultraviolet regions, records in transmittance or absorbance. Spectracord 3000 recording attachment converts most single monochromators to fast recording spectrophotometers.

The Model 146
flame photometer

Features prism monochromator, phototube detectors, internal standard or direct ratio operation. A self-contained instrument designed for speed and convenience of operation. Uses less than 5 cc of sample. Operates with any commercially available gas.



The Model 38A
Tiselius Electrophoresis Instrument

Analyzes and separates complex solutions. Permits determination of identity, concentration and composition of solutes. Widely used by biologists, pathologists, biochemists.

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We try our best, and over the years the level of quality rises.

• • •

At a certain point in a column where we distill a lot of mesityl oxide for intramural reasons, a peculiar substance was found to accumulate. Infrared spectroscopy showed it to be 4-methyl-4-penten-2-one, an unconjugated isomer of properly conjugated mesityl oxide. A busybody among us who is quick on the draw with his gas chromatography outfit then opened a bottle of our Eastman Grade *Mesityl Oxide*, numbered Eastman 582. Sure enough, a separable fraction was present, and sure enough, it was this very same isomer. Should we take the position that it is the nature of mesityl oxide to isomerize spontaneously? We decided we should not. Up went the "P" to make it Eastman P582, and down came the price to $2.30 a kilo. Even as a Practical Grade solvent, we plan to keep its isomer content below 0.5% when packed.

• • •

We are co-operating in a splendid project to measure and catalog the infrared absorption spectrum of every organic compound that can be rounded up. One observation from this experience has impressed itself: how often the infrared spectrum shows a carbonyl linkage in compounds that are not supposed to have any. "You are seeing carbonyls in your sleep," the boss chid our normally genial chief control chemist when he came in all worried and upset about finding a carbonyl dip in the spectrum of bis-(3-chloro-n-propyl) ether. But gas chromatography went on to demonstrate two fractions present to the extent of 2% and 4% respectively, and these were found by I-R to be carbonyl compounds. That is why we have shorn this ether of its capitals, italics, and Eastman number.

• • •

Our ultraviolet spectrophotometers are another thorn in our side. U-V is very good at showing isoquinoline bands, and it showed them in *1,2,3,4-Tetrahydroisoquinoline* (Eastman 7065), where there shouldn't be any. We have rehydrogenated our complete stock thereof, redistilled it, and resolved not to let it happen again. At least it was our spectrophotometer that discovered the impurity, not somebody else's.

• • •

Recently a man wanted to buy one of our chemicals in mass-spectrographically-pure grade. We told him he couldn't afford the price and turned him down flat. Nor do we know how much money he has.

All this is for the benefit of Eastman Organic Chemicals. Our current List No. 41 catalogs some 3700 of them—a large number of battlegrounds for the war against impurity. Chemists who have the List find it a handy way to make sure they don't waste time making something they can buy. For a copy, write Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).

A fast film with a quiet name

Dearly as a hunting-and-fishing editor loves to describe some high Andean stream which only a major general has ever had occasion to whip, so the photographic press dotes on miracles in making pictures with a parsimony of radiant energy that few occasions demand. We would no more discourage this than we would the game of bridge.

The fastest film that can be obtained by walking up to a film counter without previous notice and plunking down the money is labeled *Kodak Royal-X Pan Film*. It comes either as roll film or sheet film. It is grainy. The average photo-hobbyist needs it about as badly as he needs a fishing trip to the Andes, except that a roll of the 120 size lists for only 75¢.

On the other hand, take a fellow whose hobby is bridge but whose job is to record the path of a piece of metal hurtling through the twilight a thousand miles above him. Or take his classmate who needs to analyze the first microsecond of a thermonuclear explosion. These boys are not apt to mail in their negatives to us with a letter asking how come they turned out so dark. They have been in close touch with us before going out to their stations. In their behalf we have very carefully considered all the data on the *Royal-X Pan* emulsion and concluded that for the present putting it on 16mm, 35mm, or 70mm film would not be a good idea. Furthermore, the arithmetic indicates that the most sensitive regular-production films in these widths, *Kodak Tri-X Film* and *Kodak Linagraph Pan Film*, might not be quite sensitive enough.

No, this is not leading up to some new "Quadruple Grand Ducal Whoosh!-X Film." In these cases of speed-above-all what we often recommend bears the quieter name, Kodak Spectroscopic Film, Type I-D(2). *It is one of 111 special emulsions we make for astrophysicists and the like. By some tests it is faster than* Royal-X Pan, *but we are not prepared to prove this. By advance arrangement through Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N.Y., as little as 100 feet of it in 35mm perforated form can be furnished for $10, or two 100-foot 16mm rolls for $6.60 apiece (list).*

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In manufacturing *Kodak Frozen Section Stripping Film* we are attempting to perform a public service for and through pathologists. They are paying scant attention. Unless an upturn sets in soon, we shall give up.

This product is the ultimate in slow films, being endowed with no light sensitivity whatsoever. Its sole known function is to support a CO_2-frozen tissue section being microtomed. A description of the technique, stated to be quick and easy, may be found in *American Journal of Pathology, 28*, 863-873 (1952). This paper depicts a 10μ section of adenocarcinoma of the rectum showing invasion of the wall, bronchogenic squamous cell carcinoma cut at 5μ, lung tissue cut at 5μ showing edema secondary to cardiac failure, and other examples of tissues said to be otherwise difficult to handle.

The product consists of a 10μ gelatine layer atop a 30μ cellulose ester layer atop a heavier carrier base from which it is separated before use. If the gelatine layer is pre-stained, the stain transfers in seconds to the specimen. The film is supplied in unperforated 35mm rolls 25 feet long for $15 (list) by arrangement through Eastman Kodak Company, Special Sensitized Products Division. Rochester 4, N. Y. This is not the way great industrial empires are built.

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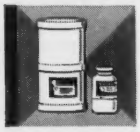

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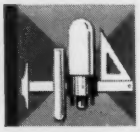

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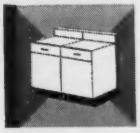

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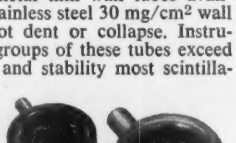

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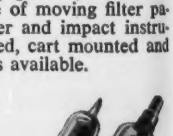

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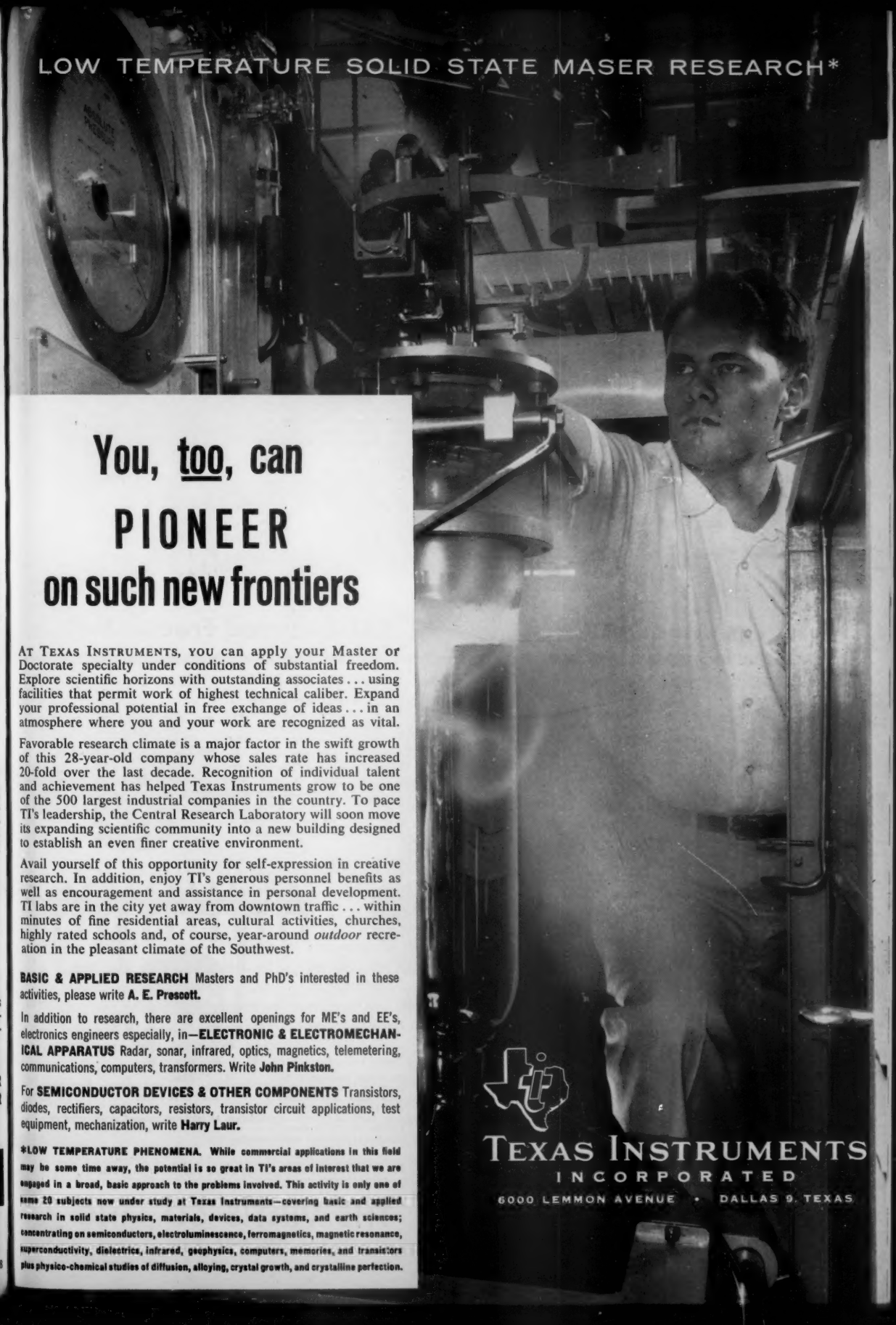

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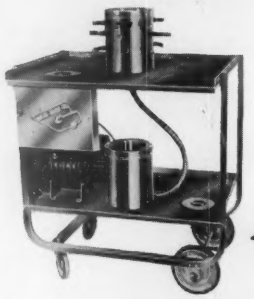

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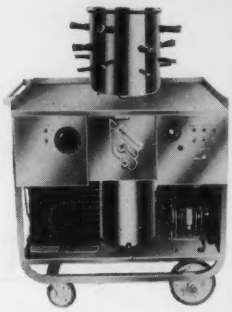

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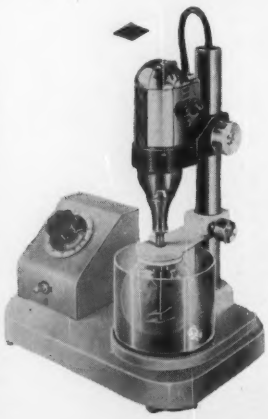

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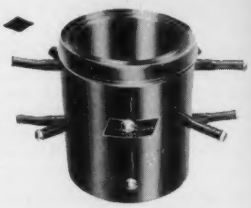

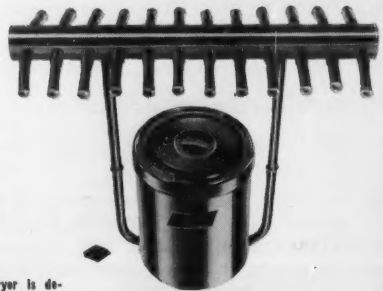

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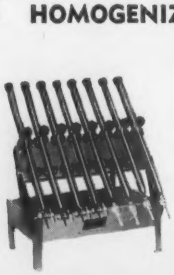

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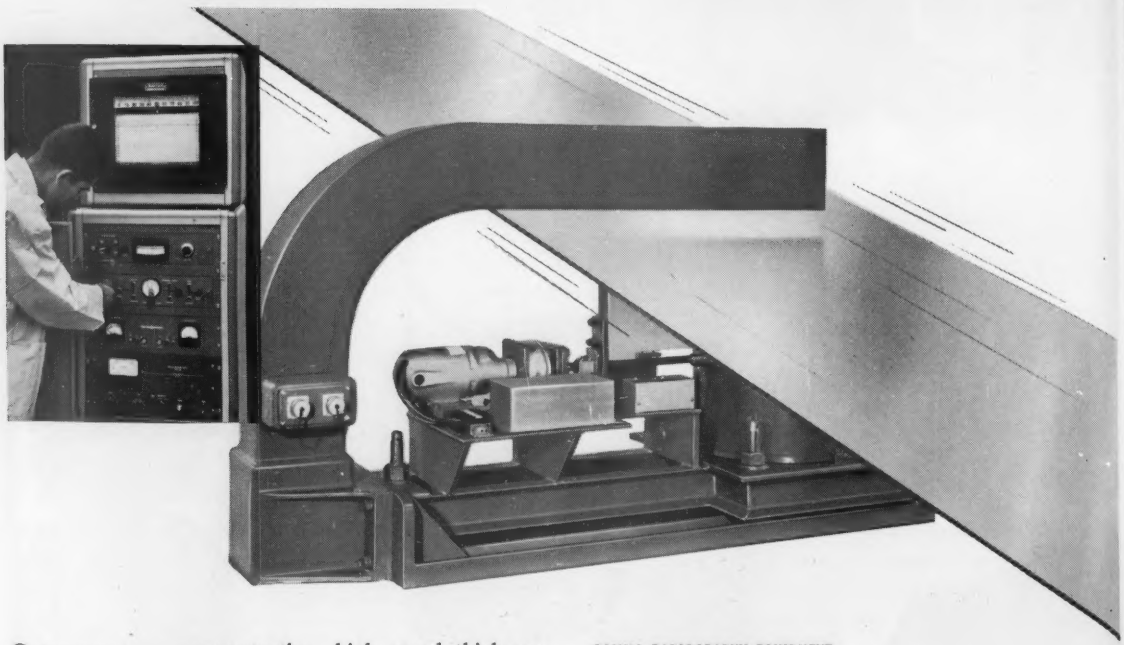

Gammascan, a non-contacting, high speed thickness gage, is capable of providing continuous measurement of deviations in a wide range of materials and thicknesses.

By utilizing gamma radiation from a shielded Cobalt 60 source and a special scintillation detection system, Gammascan indicates thickness deviations within milliseconds—deviations as small as .001" of steel. It can be linked with a chart recorder as well as servo-mechanisms for positive production control. One calibration allows 24 hours of continuous operation.

Gammascan is just one product of the constant research and development going on at Nuclear Systems. Also offered are . . .

GAMMA IRRADIATION FACILITIES
Cobalt 60 sources and lead-shielded facilities for conducting radiation research in your own laboratory.

GAMMA RADIOGRAPHY EQUIPMENT
Gamma sources and machines for radiographic inspection of weldments, castings, and solid fuel propellants.

RADIOACTIVE SOURCES
Isotope source material and encapsulation facilities available for special source requirements.

COBALT 60 TELETHERAPY SOURCES
Medical sources in standard international teletherapy capsules provided for commercial or custom installations.

CONTRACT RESEARCH AND CONSULTING
in fields related to our product line . . . including nondestructive testing in such diverse areas as gamma probing of reactor shielding and missile solid fuel propellants.

For full particulars about the new Gammascan, or any of our other products or services, contact our nearest sales office.

NUCLEAR SYSTEMS
A DIVISION OF THE BUDD COMPANY, Philadelphia 32, Pa.

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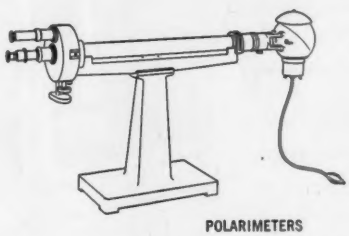
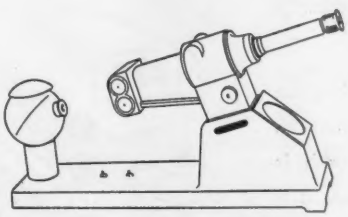
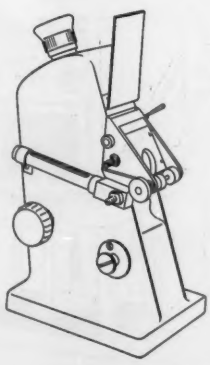


POLARIMETERS



ANOMALOSCOPE



SUGAR REFRACTOMETER

POLARIMETERS:
for clinical purposes to determine sugar in urine; for the chemical industries to examine optically active substances in chemical and pharmaceutical products.

SPECTROMETER-GONIOMETER:
to determine the refractive index of solids or fluids.

FOCOMETER:
for the measurements of focal length of objectives from 20-200 mm.

ANOMALOSCOPE:
a testing device for color blindness.

PYROMETER:
for the measurement of high temperatures, used in the manufacturing of electric light bulbs and the melting of gold and silver in industrial or physics laboratories.

TRICOLOR PYROMETER:
for true melting temperature determinations in steel, cast iron, etc.

SPECTROSCOPES:
for wave length measurements, classroom demonstrations, laboratory use.

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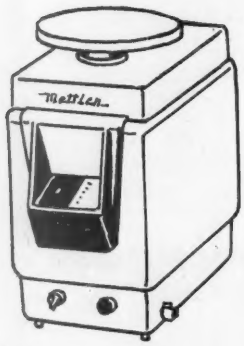
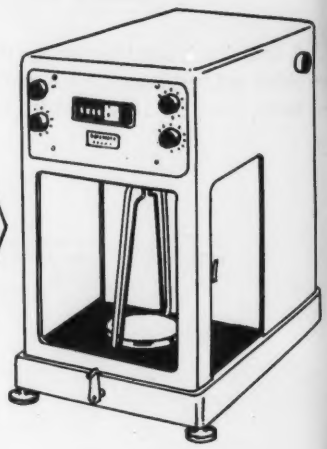
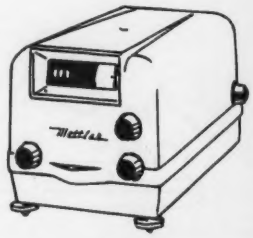


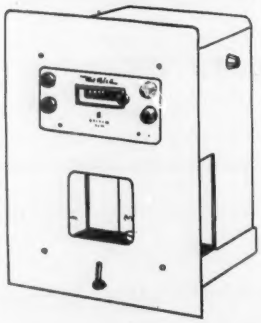


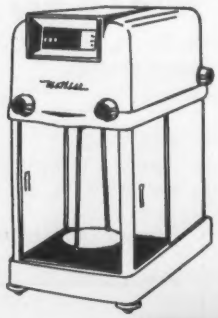
In the last 10 years the METTLER line of fine balances has grown from this single model

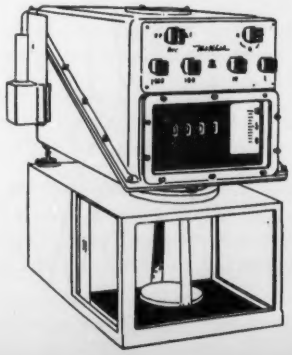
to a whole family of highly exact and useful weighing instruments. There are now 11 basic types, and each one of them is available in a number of modifications adapted to special uses. The standard calibration is in grams, but special calibrations in pounds, grains, pennyweights and carats can be supplied in some types.

METTLER balances weigh by substitution, the soundest principle of weighing. This, together with imaginative design and superb craftsmanship is the hallmark of every METTLER balance: It is your guarantee of simple, fast and trouble-free operation and of accurate results.









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SPIN 1500 ml at 26,000xG

and maintain material temperature at 0° C with

ALL-NEW MODEL HR-1

INTERNATIONAL HIGH-SPEED REFRIGERATED CENTRIFUGE

This unique combination of large capacity, higher speed and lower controlled temperature increases the value of centrifugal force as a basic research tool.

HIGH "G" HEADS: The 8-place 50 ml head delivers **40,000 x G;** the 6-place 250 ml head, **26,000 x G.** Adapters are available for use with smaller tubes. Additional heads and attachments are being developed.

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USE THE COUPON to get all the facts about this all-new and better high-speed refrigerated centrifuge from **International . . . Your Dependable Source for Centrifugal Force.**

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Please rush complete data, prices and delivery schedules on International's new HR-1 High-Speed Refrigerated Centrifuge.

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now, at low cost, the new ASCO "50" enables you to compare your present processing costs with those of

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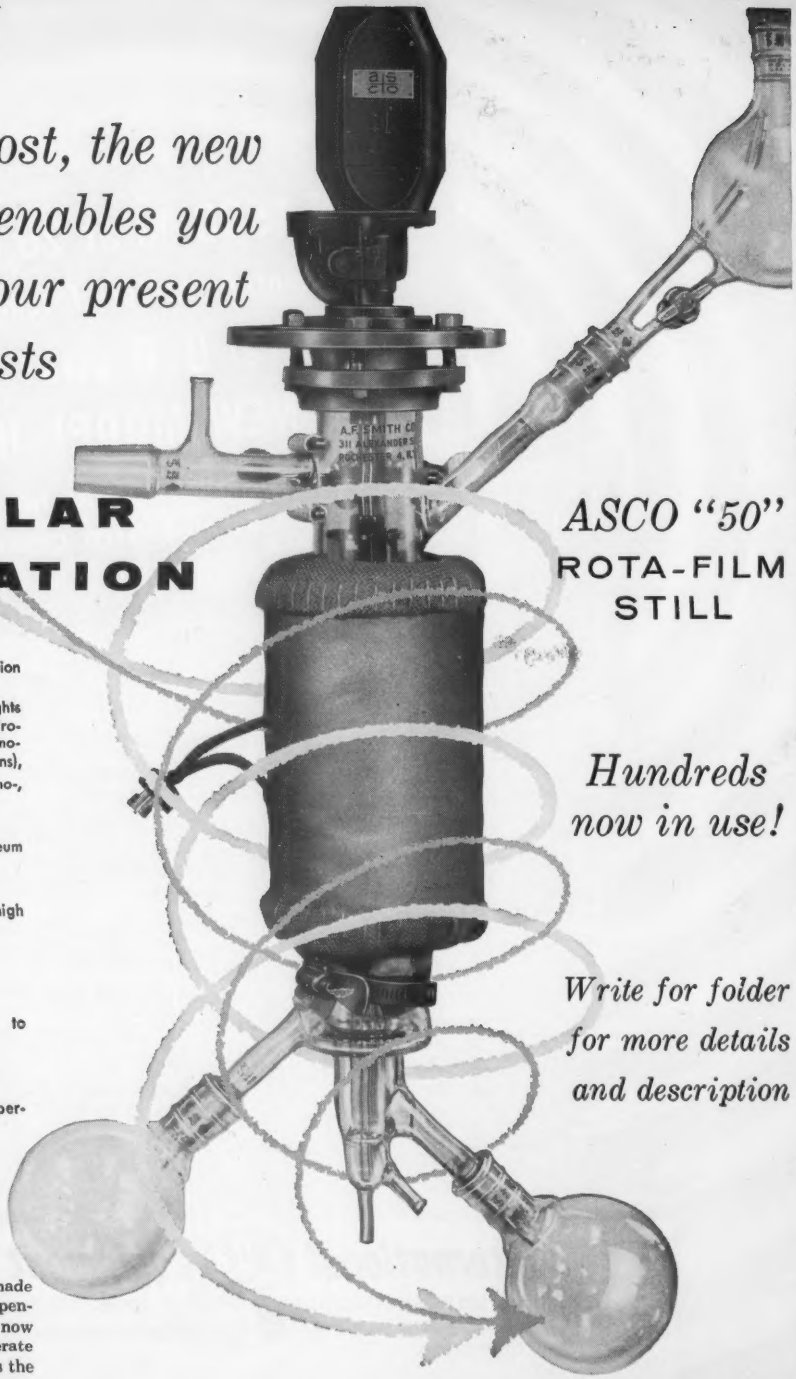

ASCO "50"
ROTA-FILM STILL

Hundreds now in use!

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With this simple-to-operate still you may...

- explore falling agitated film evaporation and distillation,
- distill materials with molecular weights ranging from 200 to 1250 weight (hydrocarbons) and some materials to 4000 molecular weight (silicones and halocarbons),
- deglycerinate and distill mixtures of mono-, di- and tri-glycerides
- distill tall oil
- distill paraffin from slack wax or petroleum residue
- deodorize oils,
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FEATURES

- Batches from 10 ml to 20 liters
- Vacuum range from atmospheric to 1 micron Hg.
- Temperature range to 450°C.
- Teflon or carbon rotor-wiper blades
- Stainless-steel (18-8 type 304) wiper-holders (Available with Hastelloy B)
- Continuous or batch feed
- All parts made of glass except wiper-holders and top plate
- UNITS MAY BE COUPLED FOR FRACTIONATION.

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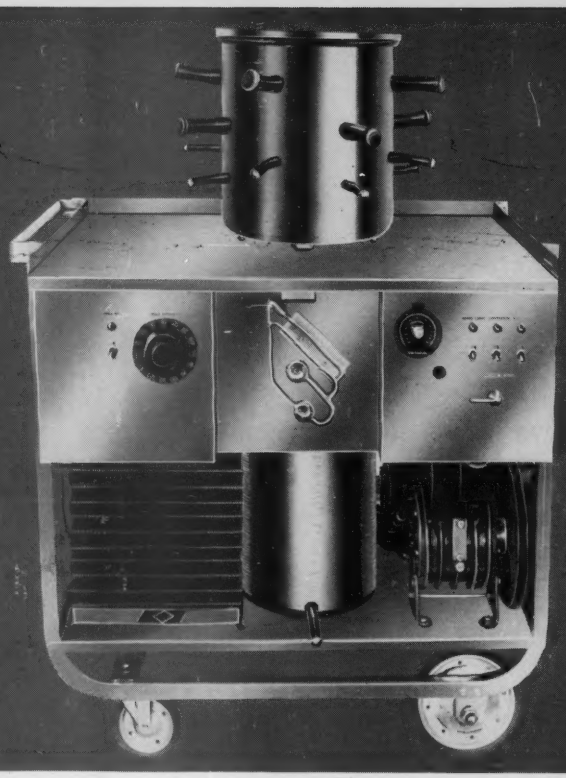

Mechanically Refrigerated Freeze-Mobile

Why freeze-drying?

Samples are frozen solid then subjected to high vacuum. When heat is applied under these conditions, moisture is gradually removed by sublimation, resulting in a dry, porous sample which can be reconstituted by adding water. Sample can be preserved indefinitely when sealed under vacuum or inert gas.

There is a VirTis Unit for every need, ranging from a micro unit with 600-ml capacity to the mechanical system shown here. Write to S/P for complete details and the new VirTis catalog.

Compact, portable freeze-drying in your own laboratory!

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- **Biological Research**—safe dehydration of hormones, vitamins, enzymes, bacteria and virus.
- **Organic Research**—purification of low vapor pressure solvents.
- **Pharmaceutical**—product preservation and dehydration.
- **Food Industry**—preservation of flavor and quality.
- **Hospital**—preserving bones, arteries, skin, etc.

This is a *complete* self-contained, all purpose unit with infrared heaters, condenser, vacuum drum, pump and gauge, and mechanically refrigerated unit. Automatically refrigerated as low as—60°C. Uniformly controlled radiant heating for fastest drying. A variety of flasks are available for manifold drying.

No. 69126—VirTis Mechanically Refrigerated Freeze-Mobile **$2,575.00**

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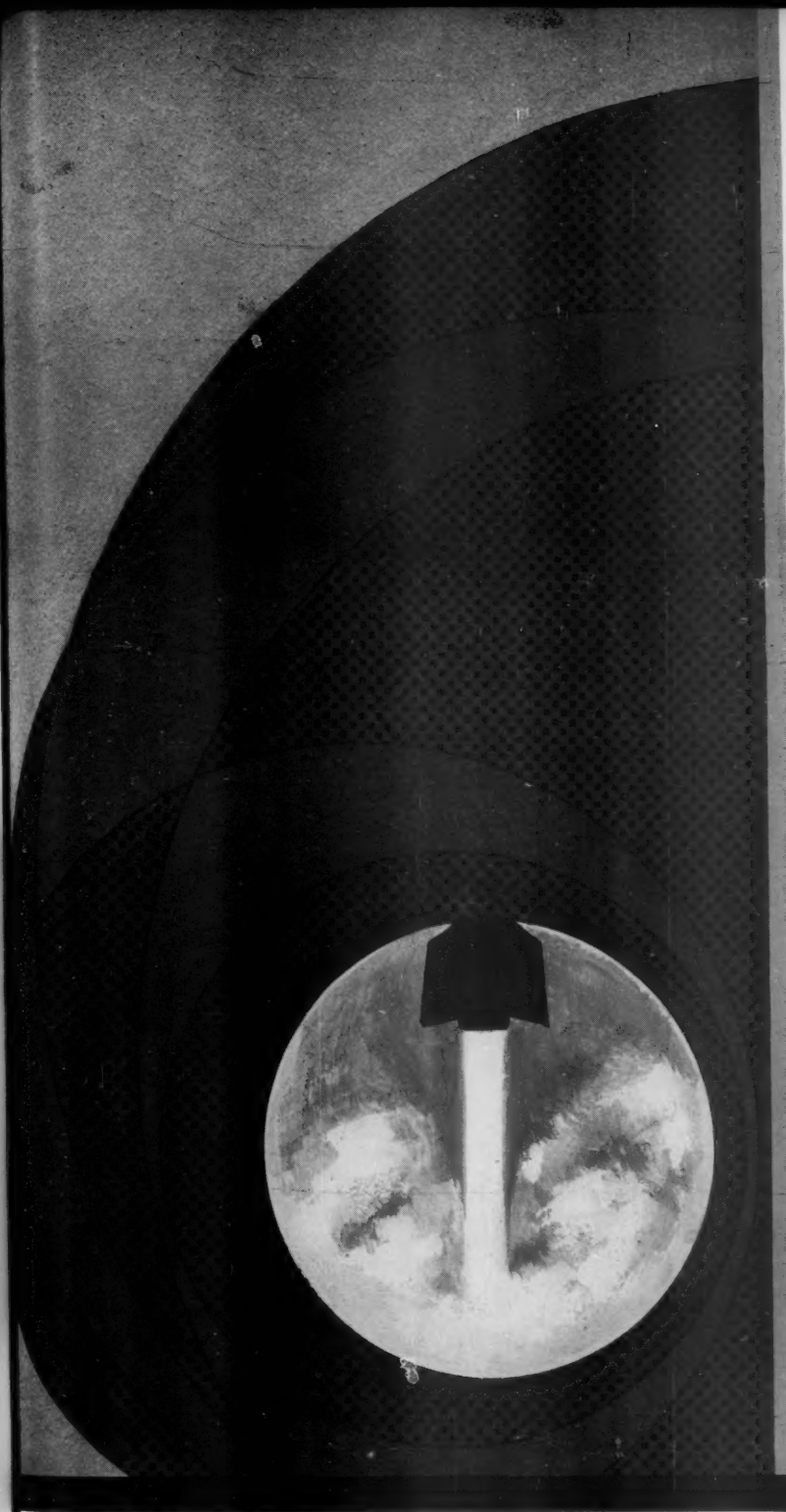


ACOUSTIC NOISE

When huge rocket engines lift a ballistic missile or satellite vehicle into the air, the thundering noise of the engines violently shakes intricate electronic components and the missile structure itself. Acoustic noise is one of the many environments that must be thoroughly explored and understood by the missile designer.

But it is expensive and impractical to conduct acoustic noise tests by operating rocket engines on the ground. Noise—of the same frequencies and amplitudes as rocket engine noise—must be produced in the laboratory.

Engineers at Avco's Research and Advanced Development Division have met this problem by designing a versatile high-intensity acoustic noise generator. Based on electromagnetic principles, it creates noise environments of the same frequency spectra as rocket or jet engines.

This successful effort is now part of the division's complete environmental testing laboratory, where it is producing information for Avco scientists and engineers responsible for ICBM nose cones.

Acoustic noise work is one of the many development programs that proceed simultaneously with theoretical and applied research at RAD. The mutual stimulation of scientists and engineers in many disciplines occurs naturally at Avco, where the search for new knowledge and its application go forward under one roof.

Research and Advanced Development is more than a descriptive title at Avco. It is a concept that promotes creativity.

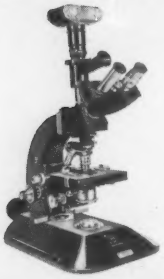
Avco

Research and Advanced Development division

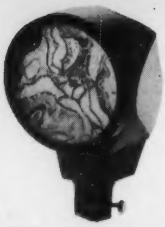
For information on unusual career opportunities for exceptionally qualified scientists and engineers, write to: Dr. R. W. Johnston, Scientific and Technical Relations, Avco Research and Advanced Development Div 201 Lowell Street, Wilmington, Mass.

REICHERT

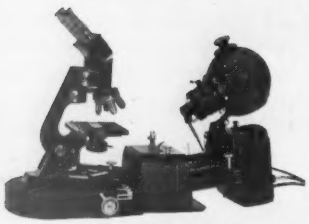
A SIGN OF VALUE
AROUND THE WORLD



RESEARCH MICROSCOPE
"ZETOPAN"



MICRO PROJECTION
VIEWSCOPE



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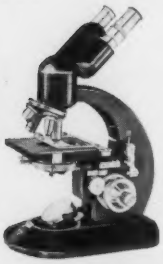
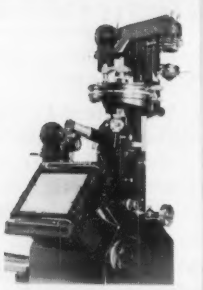
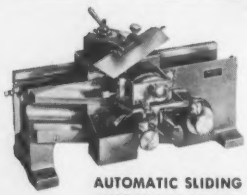


PHASE MICROSCOPE
"BIOZET"

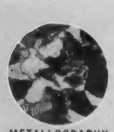


UNIVERSAL CAMERA
MICROSCOPE "MEF"



AUTOMATIC SLIDING
MICROTOME "OME"

ULTRAMICROTOME
SITTE



METALLOGRAPHY

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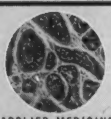

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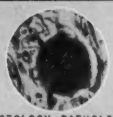

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*Pat. App'd. for

Model LRA Shown set up for continuous flow operation (Cover normally closed)

LOURDES

Automatic

Super-Speed

REFRIGERATED CENTRIFUGE

- ★ Fully automatic rotor acceleration
- ★ Push button Electro-Dynamic Braking (smooth stopping)
- ★ Accommodation for new continuous flow system*
- ★ Automatic unbalance Electrical Safety trip
- ★ Accommodates new 3 liter capacity rotor (10,000 X G)
- ★ All Lourdes' rotors directly interchangeable
- ★ Unsurpassed refrigeration efficiency*
- ★ Electric tachometer and synchronous timer
- ★ Complete safety controls

*Pat. App'd. for

The model LRA is the first automatic refrigerated centrifuge of its kind. Like the non-automatic Model LR, it has the newest and most efficient refrigeration design ever introduced. By proper placement of cutouts, baffles and deflection plates, a smooth forced air circulation system is set up. The warm air coming off the rotor flows around large surface area cooling coils on the side and bottom of the chamber. Upon emergence in the cooled form, the air flows onto all portions of the rotor. This system permits the cooling of any Lourdes' rotor from ambient to 0°C within ten minutes by spinning at slow speed. Rotor temperatures are easily maintained at 0°C and lower during full speed extended runs, and as low as —15°C at lesser speeds or for shorter runs.

By merely throwing a toggle switch, a 1 Hp. motor automatically accelerates any rotor to a pre-set speed . Lourdes' electrodynamic push-button braking system provides for smooth rotor stopping in a fraction of unbraked stopping time. A time delay relay releases the braking action at slow speed and permits the rotor to stop naturally without disturbing the sediment. This same centrifuge is now available with a ½ Hp. motor drive (Model LRA-1) to provide higher speed and force with the smaller rotors.

Each centrifuge comes adapted to accommodate the new Lourdes' continuous flow system at no additional cost. The continuous flow rotors with polyethylene liners, in addition to ease of operation, assembly and disassembly, also offer fast flow rate, high speed and force and greater collection capacity than any comparable continuous flow centrifuge. New time saving applications for these rotors are being discovered daily.

Every Lourdes' instrument is guaranteed for a period of one year and this guarantee insures customer satisfaction.

Write for New General Catalog refer to S-10-8

Catalog includes:

- Refrigerated centrifuges*
- Non-Refrigerated centrifuges
- Automatic Centrifuges
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- Multimixer—All purpose homogenizer
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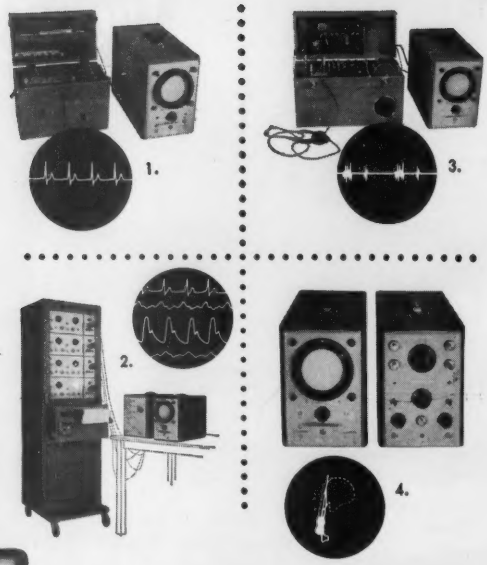

designed for
versatile, simplified
PHYSIOLOGICAL EVENT MONITORING

SANBORN
MODEL 169A
Viso-Scope

THIS precision Sanborn cathode ray oscilloscope presents the physiologic waveform under study as a bright, sharp, long-duration trace on its 5" screen—with provision for enlarging trace, instantaneous selection of 25, 50 or 100 mm/sec. sweep speeds, and photographing trace with typical 'scope cameras. Routine operation involves the use of only four controls, including focus, scale and trace brightness.

Applications indicated by the four small illustrations typify the Viso-Scope's compatible versatility with other Sanborn instruments, for monitoring in place of (or supplementing) recording. They include: (1) *single-channel* monitoring of an ECG or another physiologic event in conjunction with a Sanborn Electrocardiograph; (2) *simultaneous monitoring* of up to *four events*, by means of the Electronic Switch and 4-channel Recording System; all waveforms appear on screen simultaneously; (3) *high deflection speed* monitoring, with booster amplifier and Twin-Beam (photographic) Cardiette, of such phenomena as phonocardiograms, small animal 'cardiograms, high fidelity human ECG's, etc.; and (4) *vectorcardiography*, with the Vector Amplifier—with selection of any 7 conventional ECG leads, 3 tetrahedral or 3 cube vector leads. (Special modifications can provide for Frank, Schmitt, or other "systems", at additional cost.)

Write for detailed Viso-Scope folder, showing typical interconnection with other instruments . . . or complete catalog of more than 20 Sanborn instruments for biophysical research.

SANBORN COMPANY
MEDICAL DIVISION
175 WYMAN STREET, WALTHAM 54, MASS.

New PRES-sure clip seals PYREX stopcocks against pressure and vacuum

Now you can get stopcocks that seal tight enough for pressure and moderate high-vacuum work—at no more than standard stopcock price!

The new clip shown above holds the plug firmly against the body to prevent leakage across the bore, or out the top or bottom.

Even with this firm sealing you have no trouble valving, since the clip does not affect the plug's rotation.

Four more good reasons to insist on PYREX stopcocks

1. Wide choice of designs. Including straight bore, three-way with solid stopper; three-way "T"; two-way mercury seal; high-vacuum type with offset side arms.

2. Rugged design. Molded bodies and extra heavy sidearm tubes are accurately joined. Glass at this juncture is reworked into unusually heavy seals.

3. Precision grinding. Stopcock bodies and stoppers are precision ground to minimize leakage and freezing. All popular sizes are ☤ interchangeable.

4. PYREX brand Glass No. 7740. Resistant to chemical, mechanical and thermal shocks. Easily sealed to any PYREX brand Tubing or Apparatus.

Insist on the extras you get in PYREX Labware—the borosilicate line that has been continually developed, expanded and improved for over forty years.

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TMC Model HV-4A Photomultiplier Power Supply

here's 0.02% PER DAY STABILITY ...with continuously variable output

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Sensors Aloft

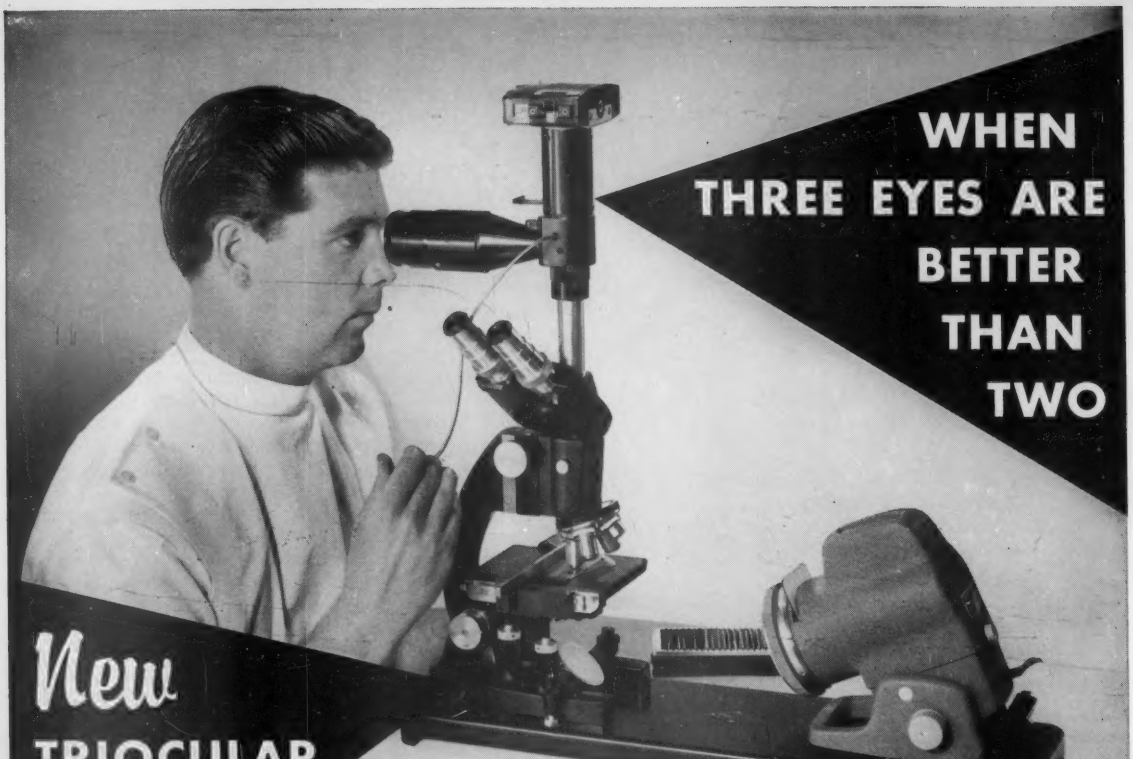
"The greatest invention of the nineteenth century was the invention of the method of invention. . . . One element in the method is just the discovery of how to set about bridging the gap between the scientific ideas, and the ultimate product."

We know of no better illustration of the validity of Whiteheads' statements (quoted above from *Science in the Modern World*) than that offered by the development of instruments to explore outer space. With satellites in orbit and the recent spectacular flight of the Pioneer in mind, it is hard to realize that the decision to attempt such launchings during the International Geophysical Year was made at a conference in Rome as recently as 1954 and that detailed plans for going ahead with a space program in this country were not formulated till 1955.

The designers of the satellites were faced with novel problems of propulsion, guidance, and communication. They had to design instruments to withstand rapid acceleration, wide temperature fluctuations, and periodic and random vibrations as well as unknown environmental variations. Moreover, the instruments had to be unprecedentedly light in weight. Rocket experiments, begun in a systematic way in 1946, had laid the groundwork for instrument design and had shown what kind of information about temperature, radiation, magnetic fields, and so on, might be procured by satellites, but these experiments had not been severely limited by the problem of weight. A rocket could carry 40 pounds or more of instruments into the upper atmosphere for a single experiment which might last only a few minutes. The satellite designers, on the other hand, had to plan to reduce the weight of the instruments to a few pounds at most and to provide enough power for them to operate for weeks rather than for minutes. They had to work against a severe time limit and had to have a superb confidence in their ability to bridge "the gap between scientific ideas, and the ultimate product." A choice had to be made, for example, between designing a transmitter with radio tubes or wtih transistors. The designers were certain at that time that tubes would give enough power, but uncertain about the performance of transistors. But transistors would be both lighter and more rugged than tubes, so they gambled upon their ability to improve them in time to meet the need. A similar choice had to be made between batteries and solar energy converters. In this case the Vanguard planners made a conservative choice and selected batteries for the first experiments, because unsolved problems of solar converters seemed to make their use too great a gamble. As an indication of the rapid progress in instrument design, a satellite now in orbit, the experimental Vanguard, which was launched last March, still faithfully transmits signals whenever it moves out of the earth's shadow and into the brilliant sunshine of interplanetary space. Had it depended upon storage batteries rather than solar energy for power, its voice would have long since been stilled.

The miles of magnetic tape now accumulating testify to the spectacular success of the designers in developing light-weight, rugged instrument systems for satellites and the moon probe. The whole point of the effort is of course to get sensing elements (or sensors, in the language of the space engineers) into space and to hook them to amplifying and transmitting systems that will get messages back to earth in an interpretable form. Already, as any attentive reader of the popular press knows, much has been discovered about the earth's magnetic field, ultraviolet radiation, the radiation belt of intense x-rays, and so on.

With the flight of the Pioneer more than one-fourth of the way to the moon, the second year of the Space Age is off to a promising start. Who can doubt that improvement in rocketry and instrumentation will lead to the further and further extension of man's knowledge of the universe?—G.DuS.



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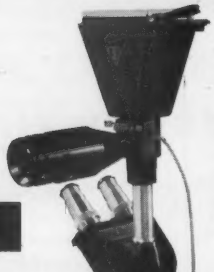

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24 October 1958, Volume 128, Number 3330 SCIENCE

Teaching Machines

From the experimental study of learning come devices which arrange optimal conditions for self-instruction.

B. F. Skinner

There are more people in the world than ever before, and a far greater part of them want an education. The demand cannot be met simply by building more schools and training more teachers. Education must become more efficient. To this end curricula must be revised and simplified, and textbooks and classroom techniques improved. In any other field a demand for increased production would have led at once to the invention of labor-saving capital equipment. Education has reached this stage very late, possibly through a misconception of its task. Thanks to the advent of television, however, the so-called audio-visual aids are being reexamined. Film projectors, television sets, phonographs, and tape recorders are finding their way into American schools and colleges.

Audio-visual aids supplement and may even supplant lectures, demonstrations, and textbooks. In doing so they serve one function of the teacher: they present material to the student and, when successful, make it so clear and interesting that the student learns. There is another function to which they contribute little or nothing. It is best seen in the productive interchange between teacher and student in the small classroom or tutorial situation. Much of that interchange has already been sacrificed in American education in order to teach large numbers of students. There is a real danger that it will be wholly obscured if use of equipment designed simply to *present* material becomes widespread. The student is becoming more and more a mere passive receiver of instruction.

Dr. Skinner is Edgar Pierce professor of psychology in Harvard University, Cambridge, Mass.

Pressey's Teaching Machines

There is another kind of capital equipment which will encourage the student to take an active role in the instructional process. The possibility was recognized in the 1920's, when Sidney L. Pressey designed several machines for the automatic testing of intelligence and information. A recent model of one of these is shown in Fig. 1. In using the device the student refers to a numbered item in a multiple-choice test. He presses the button corresponding to his first choice of answer. If he is right, the device moves on to the next item; if he is wrong, the error is tallied, and he must continue to make choices until he is right (*1*). Such machines, Pressey pointed out (*2*), could not only test and score, they could *teach*. When an examination is corrected and returned after a delay of many hours or days, the student's behavior is not appreciably modified. The immediate report supplied by a self-scoring device, however, can have an important instructional effect. Pressey also pointed out that such machines would increase efficiency in another way. Even in a small classroom the teacher usually knows that he is moving too slowly for some students and too fast for others. Those who could go faster are penalized, and those who should go slower are poorly taught and unnecessarily punished by criticism and failure. Machine instruction would permit each student to proceed at his own rate.

The "industrial revolution in education" which Pressey envisioned stubbornly refused to come about. In 1932 he expressed his disappointment (*3*). "The problems of invention are relatively simple," he wrote. "With a little money and engineering resource, a great deal could easily be done. The writer has found from bitter experience that one person alone can accomplish relatively little and he is regretfully dropping further work on these problems. But he hopes that enough may have been done to stimulate other workers, that this fascinating field may be developed."

Pressey's machines succumbed in part to cultural inertia; the world of education was not ready for them. But they also had limitations which probably contributed to their failure. Pressey was working against a background of psychological theory which had not come to grips with the learning process. The study of human learning was dominated by the "memory drum" and similar devices originally designed to study forgetting. Rate of learning was observed, but little was done to change it. Why the subject of such an experiment bothered to learn at all was of little interest. "Frequency" and "recency" theories of learning, and principles of "massed and spaced practice," concerned the conditions under which responses were remembered.

Pressey's machines were designed against this theoretical background. As versions of the memory drum, they were primarily testing devices. They were to be used after some amount of learning had already taken place elsewhere. By confirming correct responses and by weakening responses which should not have been acquired, a self-testing machine does, indeed, teach; but it is not designed primarily for that purpose. Nevertheless, Pressey seems to have been the first to emphasize the importance of immediate feedback in education and to propose a system in which each student

could move at his own pace. He saw the need for capital equipment in realizing these objectives. Above all he conceived of a machine which (in contrast with the audio-visual aids which were beginning to be developed) permitted the student to play an active role.

Another Kind of Machine

The learning process is now much better understood. Much of what we know has come from studying the behavior of lower organisms, but the results hold surprisingly well for human subjects. The emphasis in this research has not been on proving or disproving theories but on discovering and controlling the variables of which learning is a function. This practical orientation has paid off, for a surprising degree of control has been achieved. By arranging appropriate "contingencies of reinforcement," specific forms of behavior can be set up and brought under the control of specific classes of stimuli. The resulting behavior can be maintained in strength for long periods of time. A technology based on this work has already been put to use in neurology, pharmacology, nutrition, psychophysics, psychiatry, and elsewhere (*4*).

The analysis is also relevant to education. A student is "taught" in the sense that he is induced to engage in new forms of behavior and in specific forms upon specific occasions. It is not merely a matter of teaching him *what* to do; we are as much concerned with the probability that appropriate behavior will, indeed, appear at the proper time—an issue which would be classed traditionally under motivation. In education the behavior to be shaped and maintained is usually verbal, and it is to be brought under the control of both verbal and nonverbal stimuli. Fortunately, the special problems raised by verbal behavior can be submitted to a similar analysis (*5*).

If our current knowledge of the acquisition and maintenance of verbal behavior is to be applied to education, some sort of teaching machine is needed. Contingencies of reinforcement which change the behavior of lower organisms often cannot be arranged by hand; rather elaborate apparatus is needed. The human organism requires even more subtle instrumentation. An appropriate teaching machine will have several important features. The student must *compose* his response rather than select it from a set of alternatives, as in a multiple-choice self-rater. One reason for this is that we want him to recall rather than recognize —to make a response as well as see that it is right. Another reason is that effective multiple-choice material must contain plausible wrong responses, which are out of place in the delicate process of "shaping" behavior because they strengthen unwanted forms. Although it is much easier to build a machine to score multiple-choice answers than to evaluate a composed response, the technical advantage is outweighed by these and other considerations.

A second requirement of a minimal teaching machine also distinguishes it from earlier versions. In acquiring complex behavior the student must pass through a carefully designed sequence of steps, often of considerable length. Each step must be so small that it can always be taken, yet in taking it the student moves somewhat closer to fully competent behavior. The machine must make sure that these steps are taken in a carefully prescribed order.

Several machines with the required characteristics have been built and tested. Sets of separate presentations or "frames" of visual material are stored on disks, cards, or tapes. One frame is presented at a time, adjacent frames being out of sight. In one type of machine the student composes a response by moving printed figures or letters (*6*). His setting is compared by the machine with a coded response. If the two correspond, the machine automatically presents the next frame. If they do not, the response is cleared, and another must be composed. The student cannot proceed to a second step until the first has been taken. A machine of this kind is being tested in teaching spelling, arithmetic, and other subjects in the lower grades.

For more advanced students—from junior high school, say, through college —a machine which senses an arrangement of letters or figures is unnecessarily rigid in specifying form of response. Fortunately, such students may be asked to compare their responses with printed material revealed by the machine. In the machine shown in Fig. 2, material is printed in 30 radial frames on a 12-inch disk. The student inserts the disk and closes the machine. He cannot proceed until the machine has been locked, and, once he has begun, the machine cannot be unlocked. All but a corner of one frame is visible through a window. The student writes his response on a paper strip exposed through a second opening. By lifting a lever on the front of the machine, he moves what he has written under a transparent cover and uncovers the correct response in the remaining corner of the frame. If the two responses correspond, he moves the lever horizontally. This movement punches a hole in the paper opposite his response, recording the fact that he called it correct, and alters the machine so that the frame will not appear again when the student works around the disk a second time. Whether the response was correct or not, a second frame appears when the lever is returned to its starting position. The student proceeds in this way until he has responded to all frames. He then

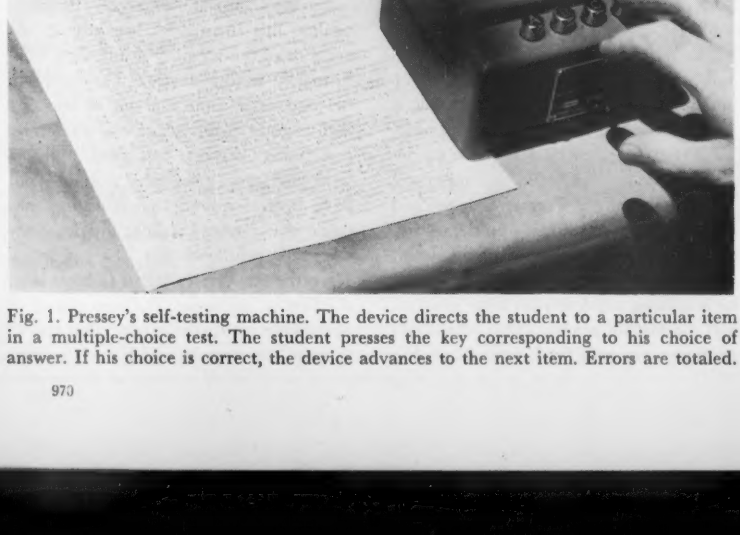

Fig. 1. Pressey's self-testing machine. The device directs the student to a particular item in a multiple-choice test. The student presses the key corresponding to his choice of answer. If his choice is correct, the device advances to the next item. Errors are totaled.

works around the disk a second time, but only those frames appear to which he has not correctly responded. When the disk revolves without stopping, the assignment is finished. (The student is asked to repeat each frame until a correct response is made to allow for the fact that, in telling him that a response is wrong, such a machine tells him what is right.)

The machine itself, of course, does not teach. It simply brings the student into contact with the person who composed the material it presents. It is a labor-saving device because it can bring one programmer into contact with an indefinite number of students. This may suggest mass production, but the effect upon each student is surprisingly like that of a private tutor. The comparison holds in several respects. (i) There is a constant interchange between program and student. Unlike lectures, textbooks, and the usual audio-visual aids, the machine induces sustained activity. The student is always alert and busy. (ii) Like a good tutor, the machine insists that a given point be thoroughly understood, either frame by frame or set by set, before the student moves on. Lectures, textbooks, and their mechanized equivalents, on the other hand, proceed without making sure that the student understands and easily leave him behind. (iii) Like a good tutor the machine presents just that material for which the student is ready. It asks him to take only that step which he is at the moment best equipped and most likely to take. (iv) Like a skillful tutor the machine helps the student to come up with the right answer. It does this in part through the orderly construction of the program and in part with techniques of hinting, prompting, suggesting, and so on, derived from an analysis of verbal behavior (*5*). (v) Lastly, of course, the machine, like the private tutor, reinforces the student for every correct response, using this immediate feedback not only to shape his behavior most efficiently but to maintain it in strength in a manner which the layman would describe as "holding the student's interest."

Fig. 2. Student at work on a teaching machine. One frame of material is partly visible in the left-hand window. The student writes his response on a strip of paper exposed at the right. He then lifts a lever with his left hand, advancing his written response under a transparent cover and uncovering the correct response in the upper corner of the frame. If he is right, he moves the lever to the right, punching a hole alongside the response he has called right and altering the machine so that that frame will not appear again when he goes through the series a second time. A new frame appears when the lever is returned to its starting position.

Programming Material

The success of such a machine depends on the material used in it. The task of programming a given subject is at first sight rather formidable. Many helpful techniques can be derived from a general analysis of the relevant behavioral processes, verbal and nonverbal. Specific forms of behavior are to be evoked and, through differential reinforcement, brought under the control of specific stimuli.

This is not the place for a systematic review of available techniques, or of the kind of research which may be expected to discover others. However, the machines themselves cannot be adequately described without giving a few examples of programs. We may begin with a set of frames (see Table 1) designed to teach a third- or fourth-grade pupil to spell the word *manufacture*. The six frames are presented in the order shown, and the pupil moves sliders to expose letters in the open squares.

The word to be learned appears in bold face in frame 1, with an example and a simple definition. The pupil's first task is simply to copy it. When he does so correctly, frame 2 appears. He must now copy selectively: he must identify "fact" as the common part of "manufacture" and "factory." This helps him to spell the word and also to acquire a separable "atomic" verbal operant (*5*). In frame 3 another root must be copied selectively from "manual." In frame 4 the pupil must for the first time insert letters without copying. Since he is asked to insert the same letter in two places, a wrong response will be doubly conspicuous, and the chance of failure is thereby minimized. The same principle governs frame 5. In frame 6 the pupil spells the word to complete the sentence used as an example in frame 1. Even a poor student is likely to do this correctly because he has just composed or completed the word five times, has made two important root-responses, and has learned that two letters occur in the word twice. He has probably learned to spell the word without having made a mistake.

Teaching spelling is mainly a process of shaping complex forms of behavior. In other subjects—for example, arithmetic—responses must be brought under the control of appropriate stimuli. Unfortunately the material which has been prepared for teaching arithmetic (*7*)

Table 1. A set of frames designed to teach a third- or fourth-grade pupil to spell the word *manufacture*.

1. **Manufacture** means to make or build. *Chair factories manufacture chairs.* Copy the word here:

   □□□□□□□□□□□

2. Part of the word is like part of the word **factory.** Both parts come from an old word meaning *make* or *build.*

   manu□□□□**ure**

3. Part of the word is like part of the word **manual.** Both parts come from an old word for *hand.* Many things used to be made by hand.

   □□□□**facture**

4. The same letter goes in both spaces:

   m□**nuf**□**cture**

5. The same letter goes in both spaces:

   man□**fact**□**re**

6. **Chair factories** □□□□□□□□□□□ **chairs.**

does not lend itself to excerpting. The numbers 0 through 9 are generated in relation to objects, quantities, and scales. The operations of addition, subtraction, multiplication, and division are thoroughly developed before the number 10 is reached. In the course of this the pupil composes equations and expressions in a great variety of alternative forms. He completes not only $5+4=\square$, but $\square+4=9$, $5\square 4=9$, and so on, aided in most cases by illustrative materials. No appeal is made to rote memorizing, even in the later acquisition of the tables. The student is expected to arrive at $9\times7=63$, not by memorizing it as he would memorize a line of poetry, but by putting into practice such principles as that nine times a number is the same as ten times the number minus the number (both of these being "obvious" or already well learned), that the digits in a multiple of nine add to nine, that in composing successive multiples of nine one counts backwards (*nine, eight*een, twenty-*seven,* thirty-*six,* and so on), that nine times a single digit is a number beginning with one less than the digit (nine times *six* is *fif*ty something), and possibly even that the product of two numbers separated by only one number is equal to the square of the separating number minus one (the square of eight already being familiar from a special series of frames concerned with squares).

Programs of this sort run to great length. At five or six frames per word, four grades of spelling may require 20,000 or 25,000 frames, and three or four grades of arithmetic, as many again. If these figures seem large, it is only because we are thinking of the normal contact between teacher and pupil. Admittedly, a teacher cannot supervise 10,000 or 15,000 responses made by each pupil per year. But the pupil's time is not so limited. In any case, surprisingly little time is needed. Fifteen minutes per day on a machine should suffice for each of these programs, the machines being free for other students for the rest of each day. (It is probably because traditional methods are so inefficient that we have been led to suppose that education requires such a prodigious part of a young person's day.)

A simple technique used in programming material at the high-school or college level, by means of the machine shown in Fig. 2, is exemplified in teaching a student to recite a poem. The first line is presented with several unimportant letters omitted. The student must read the line "meaningfully" and supply the missing letters. The second, third, and fourth frames present succeeding lines in the same way. In the fifth frame the first line reappears with other letters also missing. Since the student has recently read the line, he can complete it correctly. He does the same for the second, third, and fourth lines. Subsequent frames are increasingly incomplete, and eventually—say, after 20 or 24 frames—the student reproduces all four lines without external help, and quite possibly without having made a wrong response. The technique is similar to that used in teaching spelling: responses are first controlled by a text, but this is slowly reduced (colloquially, "vanished") until the responses can be emitted without a text, each member in a series of responses being now under the "intraverbal" control of other members.

"Vanishing" can be used in teaching other types of verbal behavior. When a student describes the geography of part of the world or the anatomy of part of the body, or names plants and animals from specimens or pictures, verbal responses are controlled by nonverbal stimuli. In setting up such behavior the student is first asked to report features of a fully labeled map, picture, or object, and the labels are then vanished. In teaching a map, for example, the machine asks the student to describe spatial relations among cities, countries, rivers, and so on, as shown on a fully labeled map. He is then asked to do the same with a map in which the names are incomplete or, possibly, lacking. Eventually he is asked to report the same relations with no map at all. If the material has been well programmed, he can do so correctly. Instruction is sometimes concerned not so much with imparting a new repertoire of verbal responses as with getting the student to describe something accurately in any available terms. The machine can "make sure the student understands" a graph, diagram, chart, or picture by asking him to identify and explain its features —correcting him, of course, whenever he is wrong.

In addition to charts, maps, graphs, models, and so on, the student may have access to auditory material. In learning to take dictation in a foreign language, for example, he selects a short passage on an indexing phonograph according to instructions given by the machine. He listens to the passage as often as necessary and then transcribes it. The machine then reveals the correct text. The student may listen to the passage again to discover the sources of any error. The indexing phonograph may also be used with the machine to teach other language skills, as well as telegraphic code, music, speech, parts of literary and dramatic appreciation, and other subjects.

A typical program combines many of these functions. The set of frames shown in Table 2 is designed to induce the student of high-school physics to talk intelligently, and to some extent technically, about the emission of light from an incandescent source. In using the machine the student will write a word or phrase to complete a given item and then uncover the corresponding word or phrase shown here in the column at the right. The reader who wishes to get the "feel" of the material should cover the right-hand column with a card, uncovering each line only after he has completed the corresponding item.

Several programming techniques are exemplified by the set of frames in

Table 2. Part of a program in high-school physics. The machine presents one item at a time. The student completes the item and then uncovers the corresponding word or phrase shown at the right.

	Sentence to be completed	Word to be supplied
1.	The important parts of a flashlight are the battery and the bulb. When we "turn on" a flashlight, we close a switch which connects the battery with the ——.	bulb
2.	When we turn on a flashlight, an electric current flows through the fine wire in the —— and causes it to grow hot.	bulb
3.	When the hot wire glows brightly, we say that it gives off or sends out heat and ——.	light
4.	The fine wire in the bulb is called a filament. The bulb "lights up" when the filament is heated by the passage of a(n) —— current.	electric
5.	When a weak battery produces little current, the fine wire, or ——, does not get very hot.	filament
6.	A filament which is *less* hot sends out or gives off —— light.	less
7.	"Emit" means "send out." The amount of light sent out, or "emitted," by a filament depends on how —— the filament is.	hot
8.	The higher the temperature of the filament the —— the light emitted by it.	brighter, stronger
9.	If a flashlight battery is weak, the —— in the bulb may still glow, but with only a dull red color.	filament
10.	The light from a very hot filament is colored yellow or white. The light from a filament which is not very hot is colored ——.	red
11.	A blacksmith or other metal worker sometimes makes sure that a bar of iron is heated to a "cherry red" before hammering it into shape. He uses the —— of the light emitted by the bar to tell how hot it is.	color
12.	Both the color and the amount of light depend on the —— of the emitting filament or bar.	temperature
13.	An object which emits light because it is hot is called "incandescent." A flashlight bulb is an incandescent source of ——.	light
14.	A neon tube emits light but remains cool. It is, therefore, not an incandescent —— of light.	source
15.	A candle flame is hot. It is a(n) —— source of light.	incandescent
16.	The hot wick of a candle gives off small pieces or particles of carbon which burn in the flame. Before or while burning, the hot particles send out, or ——, light.	emit
17.	A long candlewick produces a flame in which oxygen does not reach all the carbon particles. Without oxygen the particles cannot burn. Particles which do not burn rise above the flame as ——.	smoke
18.	We can show that there are particles of carbon in a candle flame, even when it is not smoking, by holding a piece of metal in the flame. The metal cools some of the particles before they burn, and the unburned carbon —— collect on the metal as soot.	particles
19.	The particles of carbon in soot or smoke no longer emit light because they are —— than when they were in the flame.	cooler, colder
20.	The reddish part of a candle flame has the same color as the filament in a flashlight with a weak battery. We might guess that the yellow or white parts of a candle flame are —— than the reddish part.	hotter
21.	"Putting out" an incandescent electric light means turning off the current so that the filament grows too —— to emit light.	cold, cool
22.	Setting fire to the wick of an oil lamp is called —— the lamp.	lighting
23.	The sun is our principal —— of light, as well as of heat.	source
24.	The sun is not only very bright but very hot. It is a powerful —— source of light.	incandescent
25.	Light is a form of energy. In "emitting light" an object changes, or "converts," one form of —— into another.	energy
26.	The electrical energy supplied by the battery in a flashlight is converted to —— and ——.	heat, light; light, heat
27.	If we leave a flashlight on, all the energy stored in the battery will finally be changed or —— into heat and light.	converted
28.	The light from a candle flame comes from the —— released by chemical changes as the candle burns.	energy
29.	A nearly "dead" battery may make a flashlight bulb warm to the touch, but the filament may still not be hot enough to emit light—in other words, the filament will not be —— at that temperature.	incandescent
30.	Objects, such as a filament, carbon particles, or iron bars, become incandescent when heated to about 800 degrees Celsius. At that temperature they begin to —— ——.	emit light
31.	When raised to any temperature above 800 degrees Celsius, an object such as an iron bar will emit light. Although the bar may melt or vaporize, its particles will be —— no matter how hot they get.	incandescent
32.	About 800 degrees Celsius is the lower limit of the temperature at which particles emit light. There is no upper limit of the —— at which emission of light occurs.	temperature
33.	Sunlight is —— by very hot gases near the surface of the sun.	emitted
34.	Complex changes similar to an atomic explosion generate the great heat which explains the —— of light by the sun.	emission
35.	Below about —— degrees Celsius an object is not an incandescent source of light.	800

Table 2. Technical terms are introduced slowly. For example, the familiar term "fine wire" in frame 2 is followed by a definition of the technical term "filament" in frame 4; "filament" is then asked for in the presence of the nonscientific synonym in frame 5 and without the synonym in frame 9. In the same way "glow," "give off light," and "send out light" in early frames are followed by a definition of "emit" with a synonym in frame 7. Various inflected forms of "emit" then follow, and "emit" itself is asked for with a synonym in frame 16. It is asked for without a synonym but in a helpful phrase in frame 30, and "emitted" and "emission" are asked for without help in frames 33 and 34. The relation between temperature and amount and color of light is developed in several frames before a formal statement using the word "temperature" is asked for in frame 12. "Incandescent" is defined and used in frame 13, is used again in frame 14, and is asked for in frame 15, the student receiving a thematic prompt from the recurring phrase "incandescent source of light." A formal prompt is supplied by "candle." In frame 25 the new response "energy" is easily evoked by the words "form of . . . ." because the expression "form of energy" is used earlier in the frame. "Energy" appears again in the next two frames and is finally asked for, without aid, in frame 28. Frames 30 through 35 discuss the limiting temperatures of incandescent objects, while reviewing several kinds of sources. The figure 800 is used in three frames. Two intervening frames then permit some time to pass before the response "800" is asked for.

Unwanted responses are eliminated with special techniques. If, for example, the second sentence in frame 24 were simply "It is a(n) —— source of light," the two "very's" would frequently lead the student to fill the blank with "strong" or a synonym thereof. This is prevented by inserting the word "powerful" to make a synonym redundant. Similarly, in frame 3 the words "heat and" preempt the response "heat," which would otherwise correctly fill the blank.

The net effect of such material is more than the acquisition of facts and terms. Beginning with a largely unverbalized acquaintance with flashlights, candles, and so on, the student is induced to talk about familiar events, together with a few new facts, with a fairly technical vocabulary. He applies the same terms to facts which he may never before have seen to be similar. The emission of light from an incandescent source takes shape as a topic or field of inquiry. An understanding of the subject emerges which is often quite surprising in view of the fragmentation required in item building.

Fig. 3. Self-instruction room in Sever Hall at Harvard. Ten booths contain teaching machines, some equipped with indexing phonographs.

It is not easy to construct such a program. Where a confusing or elliptical passage in a textbook is forgivable because it can be clarified by the teacher, machine material must be self-contained and wholly adequate. There are other reasons why textbooks, lecture outlines, and film scripts are of little help in preparing a program. They are usually not logical or developmental arrangements of material but strategems which the authors have found successful under existing classroom conditions. The examples they give are more often chosen to hold the student's interest than to clarify terms and principles. In composing material for the machine, the programmer may go directly to the point.

A first step is to define the field. A second is to collect technical terms, facts, laws, principles, and cases. These must then be arranged in a plausible developmental order—linear if possible, branching if necessary. A mechanical arrangement, such as a card filing system, helps. The material is distributed among the frames of a program to achieve an arbitrary density. In the final composition of an item, techniques for strengthening asked-for responses and for transferring control from one variable to another are chosen from a list according to a given schedule in order to prevent the establishment of irrelevant verbal tendencies appropriate to a single technique. When one set of frames has been composed, its terms and facts are seeded mechanically among succeeding sets, where they will again be referred to in composing later items to make sure that the earlier repertoire remains active. Thus, the technical terms, facts, and examples in Table 2 have been distributed for reuse in succeeding sets on reflection, absorption, and transmission, where they are incorporated into items dealing mainly with other matters. Sets of frames for explicit review can, of course, be constructed. Further research will presumably discover other, possibly more effective, techniques. Meanwhile, it must be admitted that a considerable measure of art is needed in composing a successful program.

Whether good programming is to remain an art or to become a scientific technology, it is reassuring to know that there is a final authority—the student. An unexpected advantage of machine instruction has proved to be the feedback to the *programmer*. In the elementary school machine, provision is made for discovering which frames commonly yield wrong responses, and in the high-school and college machine the paper strips bearing written answers are available for analysis. A trial run of the first version of a program quickly reveals frames which need to be altered, or sequences which need to be lengthened. One or two revisions in the light of a

few dozen responses work a great improvement. No comparable feedback is available to the lecturer, textbook writer, or maker of films. Although one text or film may seem to be better than another, it is usually impossible to say, for example, that a given sentence on a given page or a particular sequence in a film is causing trouble.

Difficult as programming is, it has its compensations. It is a salutary thing to try to guarantee a right response at every step in the presentation of a subject matter. The programmer will usually find that he has been accustomed to leave much to the student—that he has frequently omitted essential steps and neglected to invoke relevant points. The responses made to his material may reveal surprising ambiguities. Unless he is lucky, he may find that he still has something to learn about his subject. He will almost certainly find that he needs to learn a great deal more about the behavioral changes he is trying to induce in the student. This effect of the machine in confronting the programmer with the full scope of his task may in itself produce a considerable improvement in education.

Composing a set of frames can be an exciting exercise in the analysis of knowledge. The enterprise has obvious bearings on scientific methodology. There are hopeful signs that the epistemological implications will induce experts to help in composing programs. The expert may be interested for another reason. We can scarcely ask a topflight mathematician to write a primer in second-grade arithmetic if it is to be used by the average teacher in the average classroom. But a carefully controlled machine presentation and the resulting immediacy of contact between programmer and student offer a very different prospect, which may be enough to induce those who know most about the subject to give some thought to the nature of arithmetical behavior and to the various forms in which such behavior should be set up and tested.

Can Material Be Too Easy?

The traditional teacher may view these programs with concern. He may be particularly alarmed by the effort to maximize success and minimize failure. He has found that students do not pay attention unless they are worried about the consequences of their work. The customary procedure has been to maintain the necessary anxiety by inducing errors. In recitation, the student who obviously knows the answer is not too often asked; a test item which is correctly answered by everyone is discarded as nondiscriminating; problems at the end of a section in a textbook in mathematics generally include one or two very difficult items; and so on. (The teacher-turned-programmer may be surprised to find this attitude affecting the construction of items. For example, he may find it difficult to allow an item to stand which "gives the point away." Yet if we can solve the motivational problem with other means, what is more effective than giving a point away?) Making sure that the student knows he doesn't know is a technique concerned with motivation, not with the learning process. Machines solve the problem of motivation in other ways. There is no evidence that what is easily learned is more readily forgotten. If this should prove to be the case, retention may be guaranteed by subsequent material constructed for an equally painless review.

The standard defense of "hard" material is that we want to teach more than subject matter. The student is to be challenged and taught to "think." The argument is sometimes little more than a rationalization for a confusing presentation, but it is doubtless true that lectures and texts are often inadequate and misleading by design. But to what end? What sort of "thinking" does the student learn in struggling through difficult material? It is true that those who learn under difficult conditions are better students, but are they better because they have surmounted difficulties or do they surmount them because they are better? In the guise of teaching thinking we set difficult and confusing situations and claim credit for the students who deal with them successfully.

The trouble with deliberately making education difficult in order to teach thinking is (i) that we must remain content with the students thus selected, even though we know that they are only a small part of the potential supply of thinkers, and (ii) that we must continue to sacrifice the teaching of subject matter by renouncing effective but "easier" methods. A more sensible program is to analyze the behavior called "thinking" and produce it according to specifications. A program specifically concerned with such behavior could be composed of material already available in logic, mathematics, scientific method, and psychology. Much would doubtless be added in completing an effective program. The machine has already yielded important relevant by-products. Immediate feedback encourages a more careful reading of programmed material than is the case in studying a text, where the consequences of attention or inattention are so long deferred that they have little effect on reading skills. The behavior involved in observing or attending to detail—as in inspecting charts and models or listening closely to recorded speech—is efficiently shaped by the contingencies arranged by the machine. And when an immediate result is in the balance, a student will be more likely to learn how to marshal relevant material, to concentrate on specific features of a presentation, to reject irrelevant materials, to refuse the easy but wrong solution, and to tolerate indecision, all of which are involved in effective thinking.

Part of the objection to easy material is that the student will come to depend on the machine and will be less able than ever to cope with the inefficient presentations of lectures, textbooks, films, and "real life." This is indeed a problem. All good teachers must "wean" their students, and the machine is no exception. The better the teacher, the more explicit must the weaning process be. The final stages of a program must be so designed that the student no longer requires the helpful conditions arranged by the machine. This can be done in many ways—among others by using the machine to discuss material which has been studied in other forms. These are questions which can be adequately answered only by further research.

No large-scale "evaluation" of machine teaching has yet been attempted. We have so far been concerned mainly with practical problems in the design and use of machines, and with testing and revising sample programs. The machine shown in Fig. 2 was built and tested with a grant from the Fund for the Advancement of Education. Material has been prepared and tested with the collaboration of Lloyd E. Homme, Susan R. Meyer, and James G. Holland (*8*). The self-instruction room shown in Fig. 3 was set up under this grant. It contains ten machines and was recently used to teach part of a course in human behavior to Harvard and Radcliffe undergraduates. Nearly 200 students completed 48 disks (about 1400 frames) prepared with the collaboration of Holland. The factual core of the course was covered, corresponding to about 200 pages of the text (*9*). The median time required to finish 48 disks was 14½ hours. The students were not examined on the material but were responsible

for the text which overlapped it. Their reactions to the material and to self-instruction in general have been studied through interviews and questionnaires. Both the machines and the material are now being modified in the light of this experience, and a more explicit evaluation will then be made.

Meanwhile, it can be said that the expected advantages of machine instruction were generously confirmed. Unsuspected possibilities were revealed which are now undergoing further exploration. Although it is less convenient to report to a self-instruction room than to pick up a textbook in one's room or elsewhere, most students felt that they had much to gain in studying by machine. Most of them worked for an hour or more with little effort, although they often felt tired afterwards, and they reported that they learned much more in less time and with less effort than in conventional ways. No attempt was made to point out the relevance of the material to crucial issues, personal or otherwise, but the students remained interested. (Indeed, one change in the reinforcing contingencies suggested by the experiment is intended to *reduce* the motivational level.) An important advantage proved to be that the student always knew where he stood, without waiting for an hour test or final examination.

Some Questions

Several questions are commonly asked when teaching machines are discussed. Cannot the results of laboratory research on learning be used in education without machines? Of course they can. They should lead to improvements in textbooks, films, and other teaching materials. Moreover, the teacher who really understands the conditions under which learning takes place will be more effective, not only in teaching subject matter but in managing the class. Nevertheless, some sort of device is necessary to arrange the subtle contingencies of reinforcement required for optimal learning if each student is to have individual attention. In nonverbal skills this is usually obvious; texts and instructor can guide the learner but they cannot arrange the final contingencies which set up skilled behavior. It is true that the verbal skills at issue here are especially dependent upon social reinforcement, but it must not be forgotten that the machine simply mediates an *essentially verbal* relation. In shaping and maintaining verbal knowledge we are not committed to the contingencies arranged through immediate personal contact.

Machines may still seem unnecessarily complex compared with other mediators such as workbooks or self-scoring test forms. Unfortunately, these alternatives are not acceptable. When material is adequately programmed, adjacent steps are often so similar that one frame reveals the response to another. Only some sort of mechanical presentation will make successive frames independent of each other. Moreover, in self-instruction an automatic record of the student's behavior is especially desirable, and for many purposes it should be foolproof. Simplified versions of the present machines have been found useful—for example, in the work of Ferster and Sapon, of Porter, and of Gilbert (*8*)—but the mechanical and economic problems are so easily solved that a machine with greater capabilities is fully warranted.

Will machines replace teachers? On the contrary, they are capital equipment to be used by teachers to save time and labor. In assigning certain mechanizable functions to machines, the teacher emerges in his proper role as an indispensable human being. He may teach more students than heretofore—this is probably inevitable if the world-wide demand for education is to be satisfied—but he will do so in fewer hours and with fewer burdensome chores. In return for his greater productivity he can ask society to improve his economic condition.

The role of the teacher may well be changed, for machine instruction will affect several traditional practices. Students may continue to be grouped in "grades" or "classes," but it will be possible for each to proceed at his own level, advancing as rapidly as he can. The other kind of "grade" will also change its meaning. In traditional practice a *C* means that a student has a smattering of a whole course. But if machine instruction assures mastery at every stage, a grade will be useful only in showing *how far* a student has gone. *C* might mean that he is halfway through a course. Given enough time he will be able to get an *A*; and since *A* is no longer a motivating device, this is fair enough. The quick student will meanwhile have picked up *A*'s in other subjects.

Differences in ability raise other questions. A program designed for the slowest student in the school system will probably not seriously delay the fast student, who will be free to progress at his own speed. (He may profit from the full coverage by filling in unsuspected gaps in his repertoire.) If this does not prove to be the case, programs can be constructed at two or more levels, and students can be shifted from one to the other as performances dictate. If there are also differences in "types of thinking," the extra time available for machine instruction may be used to present a subject in ways appropriate to many types. Each student will presumably retain and use those ways which he finds most useful. The kind of individual difference which arises simply because a student has missed part of an essential sequence (compare the child who has no "mathematical ability" because he was out with the measles when fractions were first taken up) will simply be eliminated.

Other Uses

Self-instruction by machine has many special advantages apart from educational institutions. Home study is an obvious case. In industrial and military training it is often inconvenient to schedule students in groups, and individual instruction by machine should be a feasible alternative. Programs can also be constructed in subjects for which teachers are not available—for example, when new kinds of equipment must be explained to operators and repairmen, or where a sweeping change in method finds teachers unprepared (*10*). Education sometimes fails because students have handicaps which make a normal relationship with a teacher difficult or impossible. (Many blind children are treated today as feeble-minded because no one has had the time or patience to make contact with them. Deaf-mutes, spastics, and others suffer similar handicaps.) A teaching machine can be adapted to special kinds of communication—as, for example, Braille—and, above all, it has infinite patience.

Conclusion

An analysis of education within the framework of a science of behavior has broad implications. Our schools, in particular our "progressive' schools, are often held responsible for many current problems—including juvenile delinquency and the threat of a more powerful foreign technology. One remedy frequently suggested is a return to older

techniques, especially to a greater "discipline" in schools. Presumably this is to be obtained with some form of punishment, to be administered either with certain classical instruments of physical injury—the dried bullock's tail of the Greek teacher or the cane of the English schoolmaster—or as disapproval or failure, the frequency of which is to be increased by "raising standards." This is probably not a feasible solution. Not only education but Western culture as a whole is moving away from aversive practices. We cannot prepare young people for one kind of life in institutions organized on quite different principles. The discipline of the birch rod may facilitate learning, but we must remember that it also breeds followers of dictators and revolutionists.

In the light of our present knowledge a school system must be called a failure if it cannot induce students to learn except by threatening them for not learning. That this has always been the standard pattern simply emphasizes the importance of modern techniques. John Dewey was speaking for his culture and his time when he attacked aversive educational practices and appealed to teachers to turn to positive and humane methods. What he threw out should have been thrown out. Unfortunately he had too little to put in its place. Progressive education has been a temporizing measure which can now be effectively supplemented. Aversive practices can not only be replaced, they can be replaced with far more powerful techniques. The possibilities should be thoroughly explored if we are to build an educational system which will meet the present demand without sacrificing democratic principles.

References and Notes

1. The Navy's "Self-Rater" is a larger version of Pressey's machine. The items are printed on code-punched plastic cards fed by the machine. The time required to answer is taken into account in scoring.
2. S. L. Pressey, *School and Society* **23**, 586 (1926).
3. ———, *ibid.* **36**, 934 (1932).
4. B. F. Skinner, "The experimental analysis of behavior," *Am. Scientist* **45**, 4 (1957).
5. ———, *Verbal Behavior* (Appleton-Century-Crofts, New York, 1957).
6. ———, "The science of learning and the art of teaching," *Harvard Educational Rev.* **24**, 2 (1954).
7. This material was prepared with the assistance of Susan R. Meyer.
8. Dr. Homme prepared sets of frames for teaching part of college physics (kinematics), and Mrs. Meyer has prepared and informally tested material in remedial reading and vocabulary building at the junior high school level. Others who have contributed to the development of teaching machines should be mentioned. Nathan H. Azrin cooperated with me in testing a version of a machine to teach arithmetic. C. B. Ferster and Stanley M. Sapon used a simple "machine" to teach German [see "An application of recent developments in psychology to the teaching of German," *Harvard Educational Rev.* **28**, 1 (1958)]. Douglas Porter, of the Graduate School of Education at Harvard, has made an independent schoolroom test of machine instruction in spelling [see "Teaching machines," *Harvard Graduate School of Educ. Assoc. Bull.* **3**, 1 (1958)]. Devra Cooper has experimented with the teaching of English composition for freshmen at the University of Kentucky. Thomas F. Gilbert, of the University of Georgia, has compared standard and machine instruction in an introductory course in psychology, and with the collaboration of J. E. Jewett has prepared material in algebra. The U.S. Naval Training Devices Center has recently contracted with the University of Pennsylvania for a study of programs relating to the machine instruction of servicemen, under the direction of Eugene H. Galanter.
9. B. F. Skinner, *Science and Human Behavior* (Macmillan, New York, 1953).
10. K. Menger, "New approach to teaching intermediate mathematics," *Science* **127**, 1320 (1958).

The Microfluoroscope

An x-ray microscope for direct visual or photometric measurements in biological specimens is described.

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The x-ray microscope in several forms has become increasingly valuable as a complementary instrument to light and electron microscopes. It is especially suited to quantitative *in situ* measurements of the mass or thickness of microscopic structures, and to specific types of elementary microchemical analysis. Present methods of x-ray microscopy may be grouped into four classes: (i) contact methods in which the x-ray image is initially recorded or detected at unity magnification, (ii) true focusing systems in which mirrors produce images by convergent x-rays, (iii) point-projection systems in which the image is formed as a geometrical shadow cast by divergent x-rays, and (iv) scanning systems in which a likeness is recreated by a time-sequential light pattern representing the x-ray absorption in the object. These methods and their applications are described in detail elsewhere (*1*).

In all x-ray microscopes the problem of obtaining adequate intensity is serious, especially at the long wavelengths (2 to 20 angstroms) which are necessary for observing most biological material at high magnifications. This is a consequence of the inefficiency of x-ray production at the low excitation voltages and atomic numbers of targets which are practical for producing these long wavelengths. The point-projection x-ray microscope can form a reasonably bright fluorescent image at about 1 micron resolution with 5 or 10 kilovolt x-rays, but as the source diameter and excitation voltage are reduced below this, the image becomes too dim for direct viewing. The scanning system may offer some advantages in the display intensity, but it is limited ultimately by the photon noise, in the same way that the point-projection method is. Order of magnitude estimates of this ultimate speed of point-projection and scanning systems do not give much hope for direct viewing at high magnification and useful field width, especially at soft wavelengths (*2*). In reflection x-ray microscopes, some gain in intensity at long wavelengths may result from an increase in useful mirror aperture, but this increase is not enough to overcome the inherently low intensity of reflection systems in comparison with other methods of x-ray-image formation. In most cases, as we shall show, the proper contact image geometry can still provide the highest x-ray intensity at the detector for a given resolution and width of field. It has the further practical advantage, that the specimen may be mounted in air, even for viewing with ultrasoft x-rays, since the total x-ray path may be made short enough to prevent appreciable atmospheric absorption.

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Comparison with Other Methods

We may easily compare the intensities of point-projection and contact x-ray microscopes operating at the same resolution and width of field. In both methods the width of field will be limited by the obliquity of the peripheral rays passing through the edge of the specimen, and also by the lower intensity at the edge of the field caused by the longer path length and increased target absorption of these oblique rays. A practical maximum width of field may be taken as one-half the target-to-specimen distance (A in Fig. 1). For the point-projection system the minimum geometrical resolving distance, at large magnification, is equivalent to the x-ray source diameter, s. In the contact image the minimum geometrical resolving distance at the surface of the specimen farthest from the detector is given by $R = sB/A$, where B is the specimen thickness. Points on the inside of the specimen, closer to the detector, will have correspondingly better geometric resolution. Consequently, for a given width of field and geometric resolution, the contact image may utilize a source diameter larger than the source diameter of the point-projection system by a factor A/B. For example, if we wish to obtain a geometrical resolution of 0.2 micron over a 100-micron field, the point-projection system will require a source diameter of 0.2 micron located at least 200 microns from the specimen. The contact image of a 5-micron-thick specimen with the same resolution and width of field could utilize an 8-micron source diameter. Since the maximum permissible specific loading on targets of these dimensions is roughly inversely proportional to the source diameter (*3*), the total energy on the detector in the contact system will be about 40 times greater than in the point-projection system, in this typical example.

For the long x-ray wavelengths it is also necessary to consider the diffraction resolution. We shall use as the diffraction resolution criterion the width of the first Fresnel fringe at the edge of an opaque screen, divided by the image magnification. This is given by

$$r = [\lambda ab/(a+b)]^{1/2}$$

where a is the source-to-screen distance and b is the screen-to-image distance. For the point-projection case where the magnification is much greater than unity and $b \gg a$, we may call $r^2 \cong \lambda a$; and in the contact method where $m = 1$ and $b \ll a$, we may call $r^2 \cong \lambda b$, where b now corresponds to the maximum specimen thickness. If we set the diffraction resolution, defined by this criterion, equal to the geometric resolution, defined earlier, then in the example where $a = 200$ microns and $r = R = 0.2$ micron, we find that to keep the diffraction within this limit for a point-projection image, the wavelength cannot exceed 2 angstroms. This wavelength is too short to give adequate contrast in most thin sections of biological material. In order to use the point-projection system with softer radiation at this resolution, the specimen would have to be located closer to the source, thereby reducing the useful width of field. For the contact method with a specimen thickness of 5 microns, the corresponding maximum wavelength which would allow 0.2-micron resolution is 80 angstroms. This indicates that Fresnel diffraction will seldom be a problem in contact x-ray images even in the ultrasoft x-ray region, or with electron-optical enlargement.

In principle, therefore, contact-image formation stands comparison with other existing methods of x-ray microscopy very well. Not only is the contact method capable of much higher image intensity but, in the ultrasoft x-ray region useful for high-resolution biological studies, it is also capable of a higher diffraction resolution over a wider field of view than is possible with other existing systems.

As a practical matter, of course, the ideal grainless detector which is essential for making use of the contact-image capabilities does not exist. The most common materials in use for contact microradiography are the fine-grain Lippmann emulsions, such as Eastman Kodak's type 649 spectroscopic plate and Gevaert Lippmann film. Although the so-called grain size of these materials is below the resolution of the light microscope, the final developed image suffers from nonuniformity, which is clearly visible at high optical magnification. Recourt (*4*) has tried enlarging contact images made on this fine-grained film in the electron microscope in order to take full advantage of the possible resolution, but the film grain structure still presents a serious limit to this method. Ladd, Hess, and Ladd (*5*) have also used the electron microscope to improve the resolution of contact images. Their image-recording process depends upon a change of solubility of certain materials upon exposure to x-rays. A topographic image corresponding to the x-ray transmission of the specimen is thereby produced and then replicated for observation in the electron microscope. Similar investigations have been carried on by Warnes (*6*) in this laboratory, using only optical enlargement.

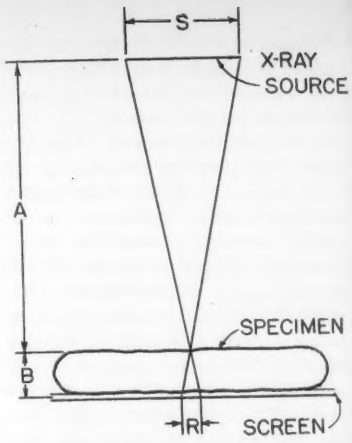


Fig. 1. Geometry of contact image formation (see text).

In an attempt to eliminate the intermediate x-ray recording material altogether, Huang (*7*) has used direct x-ray-to–electron conversion in a special photocathode which is placed at the object plane of an electron microscope. The resolution of this type of system is limited by the chromatic aberration of the photoelectrons. Again, the intensity presents serious restrictions.

Design of Microfluoroscope

The microfluoroscope under discussion is designed to take full advantage of the intensity which is attainable with contact-image formation in order to produce a direct-viewing x-ray microscope useful for the ultrasoft x-ray region. In principle, the microfluoroscope is no different from the ordinary fluoroscope. The x-rays diverge from their source, pass through the object under study, in which some are absorbed, and fall on a fluorescent screen which converts the x-ray energy to visible light which may be viewed directly. In the microfluoroscope, the size of the x-ray source, the distance from the source to the screen, and the grain size of the fluorescent screen have been scaled down by several orders of magnitude, and the final fluorescent image is then viewed with a high-power light microscope. The wavelength of the x-rays, on the other hand, has been increased to obtain higher contrast in very thin microscopic specimens.

A schematic diagram of this microfluoroscope is shown in Fig. 2. The three basic components are (i) a high-inten-

sity, microfocus x-ray tube; (ii) a thin, fine-grained fluorescent screen; and (iii) a high numerical aperture viewing microscope. At the top of the figure is the electron source, which is imaged on the x-ray target by the electron lens. The demagnification is about times 20. The target is a metal foil (aluminum, copper, tungsten, or other metal) several microns thick, glued to the outside of a heavier metal disk, which in turn is sealed to the vacuum system with a small gasket. A septum valve at the target mount permits rapid replacement of targets without opening the column to air. The fluorescent screen, on a quartz cover slip, rests on the mechanical stage of an inverted metallurgical microscope. This stage can be positioned vertically so that the screen is within 50 microns of the x-ray source. The viewing-microscope objective is focused independently of the target-to-specimen distance adjustment. The incident light illuminator is useful for the initial alignment of the specimen, for the measurement of target-to-screen distance, and for observing the condition of the target foil. The microscope itself is arranged for either visual observation, photographic recording, or direct photometric measurement of the fluorescent image.

The principal operating dimensions may be determined by the following considerations: Given the specimen thickness, B, the minimum resolving distance, R, and the width of field, F, the first two lengths determine the maximum allowable angle which the x-ray source may subtend (see Fig. 1), and the width of field determines the minimum distance from the specimen at which the x-ray source may be placed. Since the maximum permissible specific loading increases approximately inversely with the source diameter, it is important to place the source as close to the specimen as is consistent with the desired field width, and to make it as large as is consistent with the given specimen thickness and desired resolution. Only in this way can the maximum intensity benefits of the high specific loading of the microfocus source be utilized. These requirements make it advisable to have both the diameter of the target spot and the target-to-specimen distance easily adjustable under operating conditions. The minimum target-to-specimen distance should be as small as 50 microns in order to obtain maximum intensity when viewing under the highest optical magnification.

The optical components should, of course, have the highest possible numerical aperture. Oil-immersion objectives help reduce internal reflection at the surface of the cover slip supporting the screen. Since the object is self-luminous, there may be an undue amount of stray light entering the microscope which will reduce the image contrast and cause errors in photometric measurements. This can be controlled by the correct placement of stops in the objective. Some gain in optical intensity is produced by evaporating a reflecting layer of aluminum on the polished surface of the fluorescent screen. This also reduces back reflection of light from the outside of the x-ray target foil.

A photograph of the microfluoroscope is shown in Fig. 3. The viewing microscope can be translated horizontally on a short optical bench in order to provide space in which to manipulate the specimen and view it under transmitted light, as well as access to the target area, which is necessary for replacing target foils. The microfocus x-ray tube is a greatly modified Metropolitan-Vickers diffraction tube. The electron gun and anode have been altered to produce a beam of circular cross section. The objective was converted to a pinhole electron lens after Liebmann (*8*) by the addition of a pole piece (designed by W. C. Nixon). This type of lens produces "strong" electron focusing but at the same time permits a relatively long working distance, so that the target foil may be located outside the magnetic field. Under normal operation this tube can produce a focal spot 10 microns in diameter with a specific loading of 1 or 2 megawatts per square centimeter, depending upon the excitation voltage. For observation with 8-angstrom wavelength, when an aluminum target foil 3-microns thick is used, it is possible to obtain adequate intensity for direct viewing at magnification of several hundred with 9-kilovolt excitation and target current of 60 microamperes. The optical microscope is a Unitron model BMEC-3 inverted metallurgical microscope.

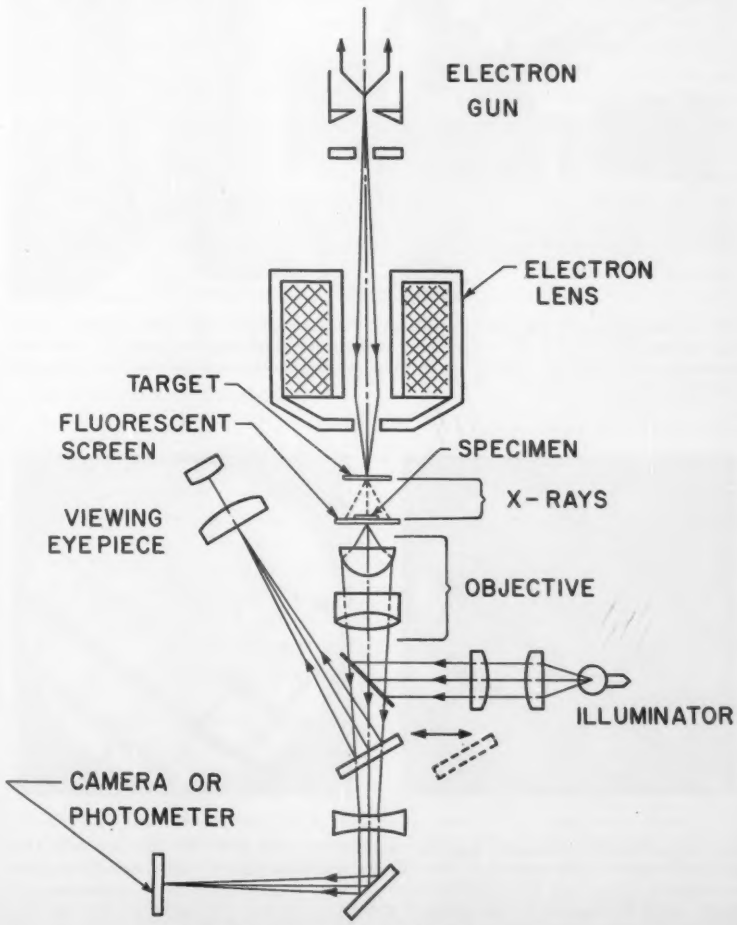


Fig. 2. Schematic diagram of the microfluoroscope.

Fluorescent Screen

The fluorescent screen itself is the most critical component of the microfluoroscope, since it must fulfill several functions and satisfy many conditions in order to provide a useful image. In the first place, the structure of the screen must be sufficiently microscopic to allow image resolution comparable to that possible with the light microscope (about 0.2 micron); secondly, the thickness of the fluorescent material must be less than the depth of focus of the light microscope if the image is to appear crisp and if photometric measurements on small objects are not to suffer from extraneous light produced outside of the focal plane of the microscope; thirdly, the screen must be made of a material which absorbs only those x-ray wavelengths which produce adequate contrast in the specimen under observation; and finally, the screen must be optically homogeneous and smooth in order to reduce light scattering. To these essential requirements we may add other desirable features of the screen such as high sensitivity to soft x-rays, uniformity over the field of view, and both chemical and mechanical stability.

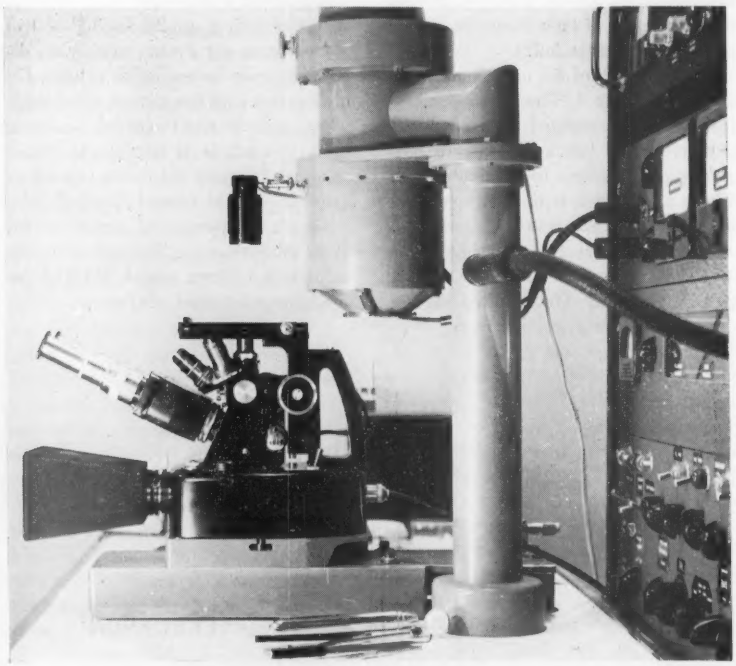
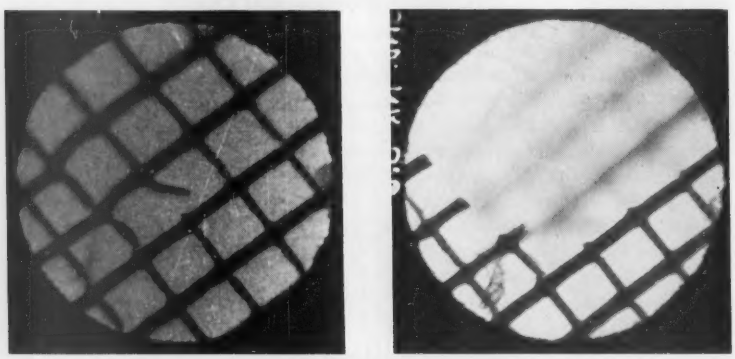


Fig. 3. Photograph of the microfluoroscope. The microfocus x-ray tube is shown at the top center. The viewing microscope is in position for mounting the specimen. For x-ray viewing, the microscope moves on the short optical bench until its objective is coaxial with the microfocus tube.

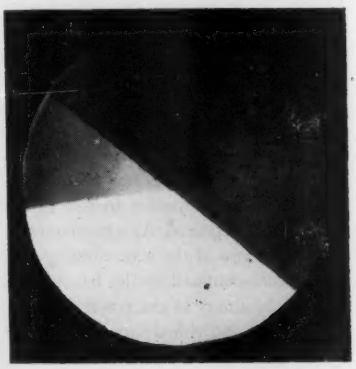


a *b*

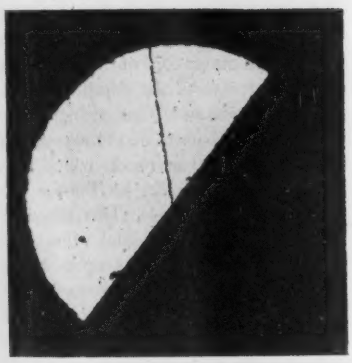
Fig. 4. (*a*, left) Microfluorograph of the resolution test grid with 1500 bars per inch. The smallest bars are 2 microns wide. Note depth of field compared with that of the light micrograph (*b*) of the identical specimen. The x-ray wavelength is 8 angstroms. (*b*, right) Light micrograph of the identical grid shown in (*a*), photographed through the fluorescent screen. Both pictures were taken with a Leitz × 90, N.A. 1.32 oil-immersion objective.

The fluorescent screen from which the microfluorographs shown in Figs. 4*a* and 5*a* were taken was made by vacuum evaporation of manganese-activated zinc orthosilicate phosphor by means of a technique similar to that used by Feldman and O'Hara (*9*) for producing transparent cathode-ray tube screens. The substrate is a quartz cover slip thin enough to allow viewing with a 100 × oil-immersion objective when mounted in the microfluoroscope. After evaporation, the cover slips are placed in a covered porcelain dish and air-baked at 1100°C for a few minutes (*10*). In order to obtain a good optical surface on the screens, so that the specimen may be viewed with transmitted light without loss of quality, we follow the baking with optical polish, using a pitch lap and tin oxide abrasive. The screen thickness may be determined by interference methods or by direct measurements with a sensitive mechanical gauge. Screens have been made by this method in thicknesses ranging from 0.2 to 1.0 micron (*11*). Figure 4 illustrates some of the characteristics of the fluorescent screen. Figure 4*a* is a microfluorograph of a silver test grid with 1500 bars per inch. The smallest bars are 2 microns wide. The grain of the fluorescent screen is clearly visible in the background. However, the resolution is not seriously affected by this structure, as can be seen by comparison with Fig. 4*b*, which is a light micrograph of the identical section of grid mounted on the same fluorescent screen. Both micrographs were taken with a Leitz 90 × N.A. 1.32 oil-immersion objective. This figure also clearly illustrates the great depth of field of the x-ray image in comparison with the light image. The portion of the grid which is broken and bent out of the focal depth of the light micrograph shows clearly in the fluoroscopic image. This great depth of field allows stereoscopic photography at the highest magnification which provides an excellent method for directly measuring the thickness of structures within a specimen.

Figure 5*a* illustrates the quality of the x-rays producing the fluoroscopic image. One quadrant of the field is covered by a 6-micron Mylar sheet while one half the field is covered with a 3-micron aluminum foil. Photometric measurements indicate that the wavelength of the x-rays producing this contrast corresponds to 90-percent aluminum K radiation. The light micrograph of the identical specimen (Fig. 5*b*) shows practically total transmission in the Mylar and total absorption in the aluminum foil. A more significant difference between the x-ray and light image is the relatively large amount of scattered radiation in the light micrograph from dust particles and, especially, from the edge of the Mylar. This scattered light, which is essential to the formation of the image, nevertheless produces large errors in light absorption measurements, especially in inhomogeneous objects or on structures with dimensions comparable with the wavelength. Scattering in x-ray images at this wavelength is entirely negligible.



a



b

Fig. 5. (*a*, top) Microfluorograph of a contrast test object. Upper right quadrant is a Mylar sheet, 6 microns thick. Half the field is covered with aluminum foil, 3 microns thick. The x-ray wavelength is 8 angstroms. The contrast results only from absorption. (*b*, bottom) Light micrograph of the identical object shown in (*a*), still mounted on fluorescent screen. The edge of the Mylar sheet is visible because of scattered light, which may cause errors in absorption measurements.

A further indication of the contrast produced by 8-angstrom x-rays is shown in Fig. 6, which is a microfluorograph of cellulose fibers ranging in thickness from 2 to 20 microns.

These evaporated fluorescent screens have distinct advantages over the fine-grained photograph emulsions which have been used to record contact x-ray images for many years. First of all, they can be made exceedingly thin, so that the light image is produced entirely within the depth of focus of the light microscope which is used to view the image. Secondly, by proper choice of the screen thickness, the target material, and the excitation voltage, it is possible to produce the x-ray image with a relatively pure, soft x-ray line spectrum without additional monochromatization, since the harder continuous components pass through the screen with little absorption. Thirdly, the excellent linearity of the fluorescent screen allows direct photometric measurements of x-ray absorption without the many difficulties usually associated with the photographic process and subsequent microdensitometry. Finally, the fluorescent material itself is comparatively durable and insensitive to light, so that the problems of specimen preparation and mounting are greatly reduced. For these reasons, such screens may be useful for other types of x-ray microscopes as well as for electron optics, for which they were originally developed.

Although improvements are being made in the quality of fluorescent screens for microfluoroscopy and in photographic emulsions for contact radiography, both methods have now approached very near to the resolution of the light optics by which they are usually viewed, and no large gain in resolution by these methods may be expected. On the other hand, enlargement of contact images by electron optical systems is a demonstrated possibility, and with the contact image geometry, diffraction and intensity limits at the ultrasoft wavelengths do not appear to be such insurmountable obstacles as they are for other methods of x-ray microscopy. It would appear likely, therefore, that any large improvement in the resolution of x-ray microscopes in the ultrasoft x-ray region would come from contact images enlarged by electron microscopy. However, the relative simplicity and speed of the microfluoroscope will make it uniquely suited to many quantitative microscopic investigations which do not require electron optical resolution. By eliminating the necessity for intermediate image recording, and by allowing specimen mounting in air and under normal illumination, this instrument approaches the simplicity of operation which is essential for routine observations and measurements (*12*).

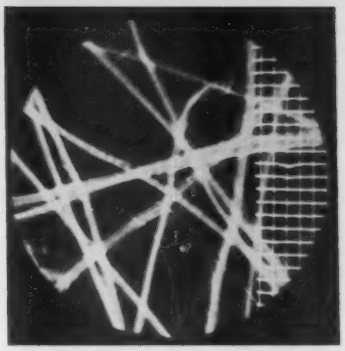


Fig. 6. Microfluorograph of cellulose fibers ranging in thickness from 2 to 20 microns, indicating the contrast range of 8-angstrom radiation. The 1500 bars-per-inch test grid indicates scale.

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10. Thomas A. Midford, research assistant in physics, contributed valuable advice in the initial stages of work with fluorescent screens.
11. Some excellent evaporated fluorescent screens have been obtained through the courtesy of Dwight Barkley of the Liberty Mirror Division of Libbey-Owens-Ford Glass Co., Brackenridge, Pa.
12. This work has been supported in part by grants from the American Cancer Society (grant p-PH-15E) and from the National Institutes of Health (grant RG-4937).

Echo Ranging in the Porpoise

Perception of objects by reflected sound is demonstrated for the first time in marine animals.

W. N. Kellogg

It has long been known that bats orient themselves in flight by the process of echo ranging or echolocation. That is, they emit a series of short high-frequency sound pulses, the echoes of which, upon their return to the bat's ears, are the means by which it avoids colliding with objects while in flight. An analysis of echo ranging in the bat undertaken by Griffin (*1*) indicates that bats may even find the flying insects which they eat in this manner. The basic principle behind the process is the same as that of Navy sonar and of the marine Fathometer or echo sounder.

That animals of the sea, especially the great whales and the porpoises, may employ a similar method to avoid colliding with objects in their pathway—as well as with the ocean bottom—has often been suggested but has never been conclusively demonstrated. Yet it is known that some of the dolphins and certain of the larger whales make many underwater noises (*2*). To date, these sounds have perhaps been most successfully studied in the case of the shallow-water porpoise, or bottlenose dolphin, *Tursiops truncatus* (Montagu). This animal, it should be noted, belongs to the order of Cetacea, suborder Odontoceti. It is one of the smaller of the toothed whales, of which the giant sperm whale is the largest representative. Kellogg, Kohler, and Morris (*3*) have made acoustical analyses of some of the submarine noises produced by *Tursiops* and have published a preliminary, although incomplete, frequency spectrum describing one class of sounds emitted.

Such facts as are at present available indicate the following:

1) The underwater noises made by the bottlenose dolphin satisfy fully the necessary acoustical and temporal requirements for echo ranging in water. Those of the short-pulse variety occur in trains or series, the individual pulses of which have a duration as short as 1 millisecond (*3*). These trains of repeated sound signals, like the cries of the bat, are particularly well suited to the production of a continuous series of echoes. In general, the pulses are complex in frequency pattern and contain many ultrasonic vibrations (*3*, *4*). Although high frequencies are by no means essential for echo ranging, such frequencies would be particularly useful under certain conditions—for example, when there is a residual background of water and wave noise.

2) The acoustic receptor of the Odontoceti is remarkably well adapated for responding to sound vibrations in water. Its structure alone suggests a kind of supersensitivity to sound (*5*). Moreover, observations of the reactions to waterborne noises made by wild or noncaptive porpoises, such as the reactions reported by Fraser (*6*) and by Howell (*7*), imply that the sense of hearing in these animals is very acute indeed. So far as is known, however, the only extensive tests of hearing on these cetaceans are those attempted by Kellogg and Kohler (*8*) and by Schevill and Lawrence (*9*). The results show that *Tursiops truncatus* is capable of reacting to sound vibrations, in water, at least as high in frequency as 80 kilocycles per second—or two full octaves above the upper frequency threshold for hearing in man.

There seems little reason to doubt, therefore, that *T. truncatus* both emits and can receive sound vibrations in water which possess the necessary characteristics for echolocation. It may consequently be said to possess an echo-ranging or a sonar system.

3) But even though this animal appears to have a kind of sonar system, there is as yet no direct evidence that he actually uses it as such. To investigate this matter further, it now becomes necessary to test captive porpoises for the avoidance and location of objects in water, after vision has been experimentally eliminated. This is, in fact, the object or purpose of the present research program. This article summarizes a series of investigations on underwater echo ranging conducted at the Marine Laboratories of Florida State University, 43 miles south of Tallahassee on the Gulf of Mexico (*10*).

Subjects and Equipment

The subjects were two bottlenose dolphins donated by the Marine Studios of Marineland, Florida, and transported 260 miles by truck to the university's laboratories. They were between seven and eight feet in length, and each was estimated to have a weight of around 300 pounds.

Although these animals are known to be both playful and intelligent (*11*), there are nevertheless marked variations in the behavior of different individuals. In the case of our own two subjects, for example, the male, a young adolescent, appeared to be quite dependent upon the more mature female and swam immediately to her side in times of stress or excitement. The female, in turn, displayed a certain reserve or sophistication by withdrawing, of her own choice, from active participation in two of the studies to be reported. As a consequence, the tests in two of the echo-ranging situations were confined to the behavior of one animal alone. In the remaining situations, both individuals took part. The animals were given the names of Albert and Betty.

The observations were made in a specially dredged pool or enclosure where the porpoises were maintained (*12*). The surface dimensions of the pool were 55 by 70 feet, and the depth was 5½ feet at low tide and 7 feet at high tide. The sides and bottom of the excavation were of soft marl or muck, which produced a poor reflecting surface for underwater sound signals. This material served, therefore, as a kind of natural baffle; its damping effect upon audio vibrations was excellent for studies of echo ranging. The pool was connected to the nearby waters of Alligator Harbor through large concrete pipes which permitted a free tidal flow both into and out of the enclosure. A 30-inch boardwalk was built around the bank at the water level, and the land area nearby was fenced off some distance back from the excavation.

A natural advantage of this testing environment was the turbidity or opacity of the water. Shoal water in this part of

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the Gulf is generally brownish during the warmer months but clears somewhat during the winter. In addition, the mud in the pool itself was continually stirred by the swimming of the porpoises, and this reduced even further the penetration of light. Regular tests of the degree of light penetration were made with a Secchi disc, and the findings were confirmed by transparency measurements with a photoelectric colorimeter. The results showed the light penetration to be as low as 10 inches in some instances, although the average penetration was closer to 20 inches. Harmless dyes were available to reduce the underwater visibility even further should this become necessary, but these were never used except in an exploratory way. The possibility that the porpoises could locate objects in the water by vision was minimized, therefore, by this turbidity.

To facilitate the lowering of underwater gear into the water, a network of horizontal wires and cables, supported by rows of small telephone poles on the bank, was stretched across the entire area of the pool about 15 feet above the water. This network was a permanent installation and was used for supporting various sorts of running tackle, which could be manipulated by assistants from the shore. With suitable rigging of this kind, one or more objects could be lowered into the water or removed from it at any desired place or places. A heavy crane mounted on a short dock protruding into one end of the pool took care of unusually heavy equipment.

The electronic accessories used in this work included several varieties of hydrophones (or underwater microphones), a heavy underwater transducer (or speaker), preamplifiers, amplifiers, oscilloscopes and oscilloscope camera, tape recorders, and air speakers. These devices were used (i) for listening to the submarine noises made by the animals while they were being tested, (ii) for recording and photographing some of these sounds, and (iii) for projecting back into the water to the porpoises the recordings of their own noises made while they were performing at echo-ranging problems.

Reactions to Submerged Targets

In the wild or natural state, *T. truncatus* catches and eats live fishes, but in captivity it must learn to eat dead (although fresh) fish. With practice it can be trained to eat from the hand. Suppose that a test or "target" food fish is thrown into the pool in such a way as to strike the water 30 feet or so from the porpoises' positions. If the test is to be critical, the animals should not be able to see either the fish in the air or the motions of the thrower. The instant the bait enters the water, both animals immediately turn and race toward it at maximum speed, although before they can arrive at the spot, the fish, if fresh, will have sunk beneath the surface. The bait is by then not visible to human observers on the bank or to the animals, yet one or the other of the porpoises never fails to retrieve it and usually surfaces almost immediately with the fish in its mouth. The whole procedure takes but a few seconds. There is no exploratory or searching behavior whatever.

What, then, is the sensory mechanism for accomplishing this trick? Obviously it cannot be a visual mechanism in such turbid water. It cannot be an olfactory mechanism, for the sense of smell does not exist in these animals (*13*). The olfactory bulbs are missing altogether, and the nostrils or blowhole is closed during submersion. Gustatory reception seems highly improbable, since the chase and seizure are much too fast for any tasting to take place. The response is like that of a dog picking up a stick on the run. There remain the tactual and temperature senses, and audition. We are forced to infer by the process of elimination that the acoustic receptor must be the sensory channel which is employed.

A deduction of this kind is confirmed by underwater listening to the animals' sounds as the chase takes place. Although porpoise sound signals may be entirely absent before the target fish strikes the water, the noise of its splash produces a torrent of sputtering sound pulses as both animals dash toward the target. When the seizure is complete, the sounds again subside.

To investigate this phenomenon in a more systematic way, the following tests were conducted:

1) Objects of various sorts were thrown or lowered into the water so as to make a splash upon entering. These included BB shot, pebbles, fishes, and 4-foot poles. Such objects also served as echo-ranging targets after submersion.

2) Streamlined or "teardrop" objects were silently lowered into the water without surface noise, yet they served, upon submersion, as targets for reflected sound waves.

3) Surface splashes alone were produced, but no underwater target was furnished. This was accomplished in several ways, although most effectively by dropping water in measured quantities upon the surface of the pool.

The major results obtained from these tests are enumerated below:

1) If the pool was perfectly quiet, even a single BB shot tossed into the water would elicit an underwater beaming response on the part of the porpoises.

2) Water dropped upon the surface which created a splashing noise sufficiently different from the background noise to be perceived was also followed by bursts of exploratory sound pulses, although these were likely to be of only momentary duration. A single drop of water from a medicine dropper did not cause enough surface noise to elicit this reaction. Under favorable conditions, however, a half-teaspoonful of water dropped from a height of 5 or 6 feet would elicit exploratory sound pulses. The splashing of a stream of water from a hose did the same thing. But since no echoes were returned after the porpoises' original sound bursts, the pattern of pulse signals in these cases was no more than exploratory and ended after a single burst.

3) A solid object immersed with complete quietness, on the other hand, produced no echo ranging until the animals happened to make sporadic exploratory ranging signals. A delay of 10 or 15 seconds might therefore result after a streamlined target had been lowered in this manner. Yet if the same target was dropped with a splash, this was at once followed by a continuous sound pattern. The splash appeared to serve as a cue for the production of the sound signals, and if echoes were returned from the original burst, the beaming continued.

The behavior of Albert, who learned to take fish from the hand (Betty would never consistently do this), was particularly significant in this connection. It was never necessary to signal or call the porpoise when a fish was inserted into the water—even from behind a screen which concealed all movement from the air. During feeding he would make occasional exploratory bursts of sound pulses which might be compared to "glancing" or "looking" in terms of vision. These bursts were usually from 1 to 2 seconds long and occurred every 10 seconds or so. He appeared to be "searching" for the fish. As soon as the fish was submerged (or as soon as the beaming signals produced echoes), the pattern of sounds would change. Discrete bursts of sound pulses would now be separated by intervals no longer than a second or two. As the porpoise moved toward the tar-

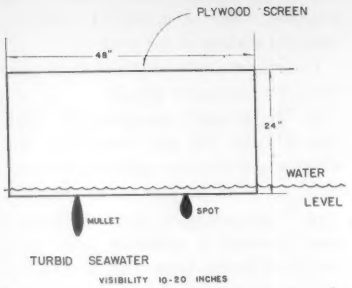

Fig. 1. Arrangement for presenting the stimuli in the fish-discrimination experiment. On any given trial, a spot (the preferred fish) and a mullet (the nonpreferred fish) were lowered simultaneously into the water from behind the plywood screen. The spot projected approximately 6 inches below the screen, the mullet 12 inches. A trial began when the fishes were submerged and ended when the porpoise took or touched either fish. The positions of the "positive" and "negative" fishes were randomly rotated from trial to trial.

get, the intervals between bursts were eliminated altogether.

While making these sounds and approaching the target, the animal would continually oscillate its head or reorient its body from right to left through an arc of perhaps 10 degrees, as a human being might when employing binaural localization. If the target fish was moved laterally under the water as Albert approached, the porpoise immediately turned so as to keep the stimulus in his sagittal plane, continually making small head oscillations at the same time.

Avoidance of Obstacles

The ability to avoid submerged objects while swimming was examined in these animals by immersing a series of obstructions which completely bracketed the swimming area. The obstacles used in these tests were light poles or posts 52 inches long. They therefore subtended most of the vertical distance between the surface and the bottom. The poles were made of galvanized sheet metal and were triangular in cross section, each side being 2 inches wide. Thirty-six of these poles were suspended over the water by rigging attached to the overhanging cables and lowered simultaneously by assistants at a predetermined signal. The poles were arranged in a regular geometrical pattern, the rows and columns of which were 8 feet (about one porpoise length) apart.

Since these obstructions were of metal and were suspended freely from above, they were extremely sensitive to contact stimuli. If touched or struck lightly either in air or in water, they gave off a metallic, bell-like ring or ping. Metallic noises of this sort made under the water could be heard by means of the hydrophone and regular underwater acoustical gear. They could also be recorded on magnetic tape along with porpoise sound signals. The metallic sounds served therefore as a means of automatically recording the collisions which the porpoises made with any of the submerged obstacles.

In the first 20-minute session of this sort there was a total of four collisions for both animals. So far as we could tell, these were made after the body of a porpoise had actually passed an obstruction. It appeared that the horizontal tail flukes of one of these small whales must have touched an obstacle as the animal was in the process of turning into a new alley. The second session was better than the first, and all subsequent trials were perfect, showing no collisions whatever. It looked as though the subjects had rapidly *learned* to navigate through the maze of obstructions in the limited swimming space allowed them. In one series of observations made during the dark phase of the moon, in nearly total darkness at night, there were also no errors.

As a final test we broadcast back to the animals, while they were swimming through the field of obstacles, tape recordings of their own noises which had been made during an earlier session in the same situation. The sounds were projected by a heavy Navy transducer, type 1-K. But the projected noises seemed not to affect the accuracy or the speed of their swimming in any way. And there were no collisions.

The most reasonable interpretation of this result appears to be that the porpoises were able to distinguish their own sound signals from the artificially produced interference. This interpretation finds support in the recent observations of Griffin (*14*) and of Griffin and Grinnell (*15*) that distracting or jamming sounds do not seriously disturb the echo-ranging ability of the bat.

Fish Discrimination Experiment

At first our two subjects were fed on mullet, *Mugil cephalus* (Linnaeus), but they soon began to refuse this fish. It therefore became necessary to supply them with a fish called spot, *Leiostomus xanthurus* (Lacépède), which they ate readily. Mullet thrown into the water would be chased but rejected. If held in the hand, a mullet would be approached but not taken.

As a consequence of this behavior, the question arose whether the animals could discriminate between preferred fish (the spot) and nonpreferred fish (the mullet) without seeing either fish. The fish-discrimination experiment was planned to examine this possibility. The discrimination cues were differences in the sizes of the preferred and the nonpreferred stimuli. To this end, mullet were selected for the experiment which were about twice as large in over-all length as the spot.

The general arrangement of the experiment is shown in Fig. 1. A rectangular screen of marine plywood was mounted solidly at the end of a 15-foot dock which projected into the pool. The screen was placed in such a way that its bottom edge was 1 to 2 inches below the surface of the water. From behind the screen, which concealed visible movement in the air, a spot and a mullet were silently lowered into the water at the same time. The tail of the spot was held by the experimenter so that the body of the fish projected approximately 6 inches below the bottom of the plywood screen. The mullet was held so as to project 12 inches below the screen. Every effort was made to eliminate all water noises as the fishes were inserted. That this was successfully accomplished was periodically checked by underwater listening. As in any discrimination experiment, the positions of the positive and negative stimuli were randomly rotated from trial to trial, although the absolute point of insertion of each fish was held constant with reference to the edges of the plywood screen.

Since the subject (Albert) was by this time well practiced in taking foodfish from the hand, he would approach the end of the dock whenever human beings came near it and wait there to be fed. Generally he lay at the top of the water, 3 to 10 feet from the plywood screen, where he would ogle the experimenters first with one eye and then with the other, submerging for a few inches between breaths, which occurred rather rapidly in such instances. A regularly timed trial began with the immersion of the two stimuli and ended when the porpoise took or touched either fish. If

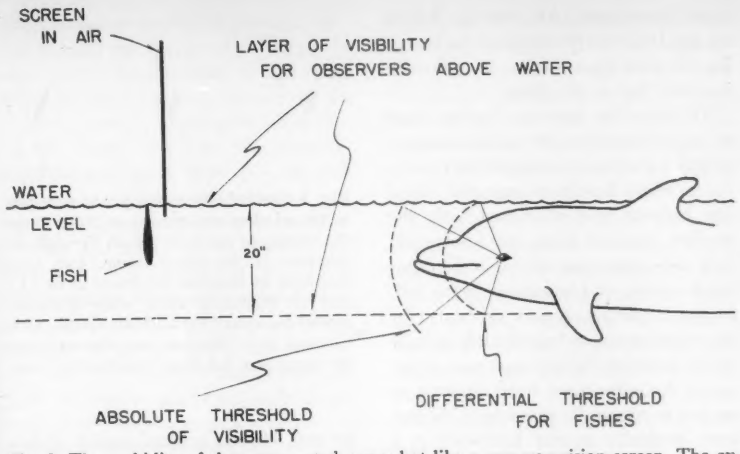

Fig. 2. The turbidity of the water acted somewhat like a one-way-vision screen. The experimenters above the water level could see sufficiently far beneath the surface to observe the porpoise's head and mouth, but the animal could not detect the target fishes in a horizontal direction. The difference between the absolute threshold for distance and the differential threshold—or the threshold of discrimination between the target fishes—is also illustrated in this figure.

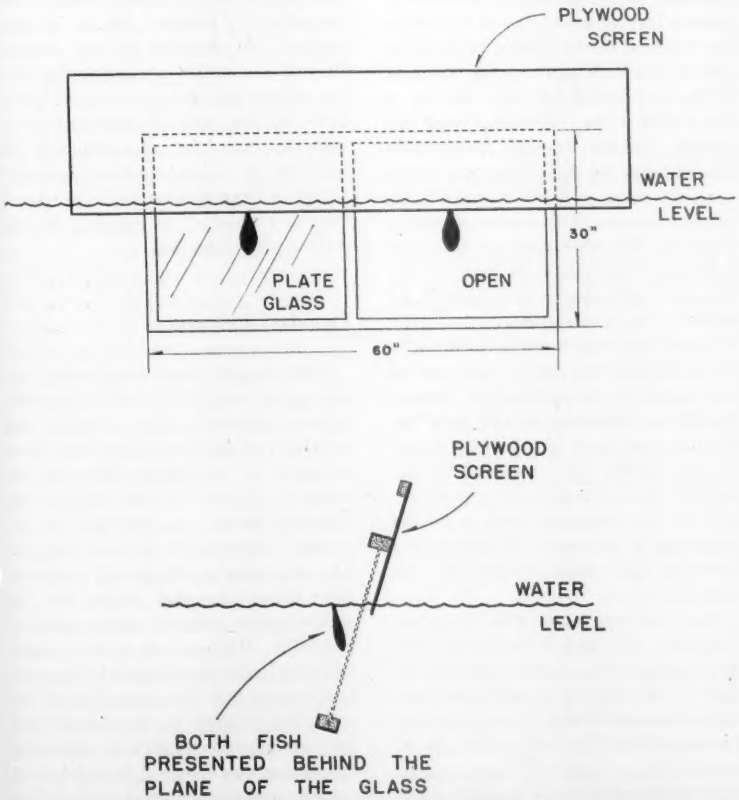

Fig. 3. (Top) Front view and (bottom) side view of the apparatus used in the window experiment. The porpoise was required to distinguish between two fish (spot) which were identical in visual appearance. The fish were presented simultaneously, but one was behind a sheet of plate glass. The glass was randomly shifted between the right and left windows.

the spot was taken, this was counted a successful discrimination. The touching or taking of the mullet was scored as an error.

Because Albert did most of his approaching at or very near the surface, it was not difficult for observers on the dock above him to tell his position with reference to the target fishes, in spite of the turbidity of the water. At the same time, the subject himself could not detect the stimuli by visual means because of this turbidity. The situation in fact possessed some of the characteristics of a one-way-vision screen, the advantage being all in favor of the experimenters. The diagram in Fig. 2 should make this clear.

A distinct difference was found to exist between the limits of visibility, as measured by the Secchi disc, and the limits of discriminability between fishes of different size, as tested by human observers under water. The Secchi disc used in these studies was a circular white reflecting surface, 20 centimeters in diameter, which was submerged until it became invisible. The procedure gave an absolute threshold of visibility measured vertically in inches from the surface of the water.

By means of special observations made by skin-diving human beings, horizontal Secchi readings in the pool were compared with vertical readings. Similar tests were made of the maximum horizontal distance, under the water, from which it was possible for a human being to distinguish between a 12-inch mullet and 6-inch spot. The horizontal and vertical Secchi readings were on the whole equal, but the horizontal discrimination threshold was found to be about one-half the absolute Secchi threshold. A Secchi measurement of 20 inches read from the surface could be translated therefore into a horizontal differential threshold between the two fishes of approximately 10 inches. The manner in which this affected the visual capacity of the porpoise is shown schematically in Fig. 2.

Regardless of these limitations, however, it soon became apparent that discrimination of a high order was taking place in the fish-discrimination experiment. In the first daily session of 16 trials, Albert committed four errors. The number of errors decreased irregularly upon successive sessions until none at all occurred. The final 140 trials—some made in near-total darkness at night—gave no errors whatever. The time per

trial was not affected—that is, it was not increased—during the night sessions. If vision had played any part in the selection of the preferred fish, a reduction in illumination would certainly have made the task more difficult. It should consequently have increased the response time, and it might also have introduced errors.

Listening and underwater recording which were conducted throughout the experiment showed also that the porpoise reacted to the insertion of the fishes by increasing at once both the intensity and the continuity of his sound signals and by surging forward toward the targets as the signals increased.

Window Experiment

It may still be assumed by some that, in spite of the turbidity of the water, visual discrimination was not really excluded in these studies. Is it possible that Albert was able to distinguish between the fishes of different size by some superhuman ocular ability? To answer this objection, a new experiment was designed in which the use of vision would prove actually to be detrimental and confusing. This experiment is referred to in the present report as the window experiment.

Like the fish-discrimination experiment, the window experiment was also a discrimination experiment, but in this case the two stimuli to be discriminated were spot (preferred fish) identical in visual appearance. Both of the spot offered on any trial were equally visible, although one of them was unavailable or unattainable since it was presented behind a sheet of plate glass. The unavailable spot was the negative stimulus and the available spot the positive stimulus. A diagram of the apparatus which was used is shown in Fig. 3.

A rectangular frame of angle iron, 30 by 60 inches, contained a square plate-glass window which would slide to the right or left so as to fill one half of the rectangle. The position of the covering glass on any trial was randomly determined. The target fishes were silently inserted from behind a plywood screen so that no movement from the air could be detected by the subject.

Both of the spot were held the same distance behind the plane of the glass, as indicated in Fig. 3 (bottom). In order to reach the available fish, it was necessary for Albert to insert his mouth several inches into the open aperture of the metal framework. An error or failure on any trial would consist of his bumping the plate-glass window or approaching very close to the glass.

To induce the porpoise to place a part of its head inside of the metal frame required a great deal of preliminary training, as might have been expected. All of this training was conducted with the window removed from the framework. Spot were sometimes offered in the right-hand opening and sometimes in the left. In the beginning, it was necessary for the experimenter to hold the fish in front of the plane of the plywood screen, exposing his submerged hand as well as the fish to Albert. By easy stages, the fish were gradually moved backward into and through the framework, as is indicated in Fig. 4.

During the experiment itself the window was adjusted at the beginning of the intertrial interval—that is, immediately after Albert had taken the fish for the preceding trial and while he was submerged and eating the fish (as revealed by underwater listening). In order to control for the sound caused by sliding the window, the movement of the glass was always made in two steps or stages. It was first pushed half way—that is, to the middle of the framework. From this central position it was subsequently moved either the rest of the way, in the same direction, or it was returned to its original position. This two-stage process produced the same sequence of apparatus noise following each trial, but the noise by itself gave no indication of the final location of the glass.

The trials were timed as in the fish-discrimination experiment, and records were made of the approximate starting position on each trial as well as of the direction and speed of swimming during a trial. In 202 trials recorded in this manner, there occurred not a single error, nor even what appeared to be the beginning of an error. No approaches whatever were made toward the fish behind the glass.

On the average it took Albert longer to complete a trial than it had in the fish-discrimination experiment, possibly because of his aversion to putting his nose within the metal frame. Later trials were somewhat faster than earlier trials, showing the effect of practice. Some sessions were conducted in nearly complete darkness at night, but this again caused no change whatever in the accuracy of the performance or in the latency of responding.

The porpoise, in fact, ultimately came

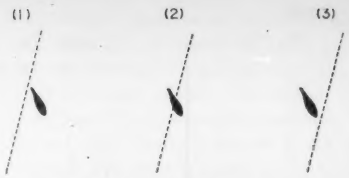

Fig. 4. Preliminary training was necessary in the window experiment in order to get the animal to insert its mouth through the aperture of the metal frame. Fish were first held in front of the frame as in (1), and on successive trials were gradually moved backward through the frame, as in (2) and (3). The glass was removed from the apparatus for these habituating trials.

up with his own original version of how the problem should be solved. He developed the habit of stationing himself in front of the open window as soon as he had eaten the fish from the preceding trial and before the minimum intertrial interval set by the procedure had elapsed. He got ready, in other words, immediately after the movement of the glass and waited a few feet away for the available or "positive" fish to be submerged. He appeared to have learned through association or conditioning that the positive stimulus would come in the open window, and he distinguished at once the opened from the unopened. All this time the animal sputtered intermittently, as he made what might be termed "auditory glances" in listening for the forthcoming target fish.

Plexiglas Experiment

Even though these experiments dispose pretty well of the visual discrimination hypothesis, there remains the possibility that Albert may have been attracted to the target fishes by the chemical stimulus of taste and that his behavior should not, therefore, be accounted for in terms of echo ranging. The responses to submerged nongustatory targets discussed earlier in this article argue strongly against such a possibility. However, as a final check upon the notion that chemical substances in the water may have served as an uncontrolled variable in the window and fish-discrimination studies, an additional experiment was arranged in which food rewards were eliminated altogether. The motivating principle in this instance was avoidance or punishment. The general plan of the experiment, which is here referred to as the Plexiglas experiment, is illustrated in Fig. 5. Both of the por-

poises served as subjects in this situation.

A submerged net of wire fencing 5 feet in height was stretched tightly across the width of the pool at the center. It formed a fixed barrier or partition dividing the water area into two approximately equal parts. The wire in the fencing was ⅛ inch in diameter and was woven into squares 5 inches to the side. The net was supported by floats at the surface and was weighted at the botton. Two openings 5 feet wide, located near the middle of the barrier, were the only passages or doorways from one half of the pool to the other. A large curtain of black war-surplus plastic suspended from above could be raised or lowered so as to block or cover both openings.

One of the openings could also be closed by a rigid sheet of clear Plexiglas, as is shown schematically in Fig. 6. Tackle from the shore permitted the Plexiglas to be moved laterally so as to block either hole. With the black curtain raised, the porpoises were therefore confronted with a kind of choice apparatus which required them to distinguish between the doorways in the wire fencing, one of which was blocked by a solid but invisible Plexiglas door.

Two other nets—which might be called "motivating nets"—were placed at the ends of the pool, one at each end, parallel to the barrier net. These motivating nets were movable and were used to induce the animals to pass from one side of the barrier to the other. Since porpoises tend to avoid physical contact and will shy away from any strange or unusual object, they would avoid the motivating net behind them by escaping into the open area of the opposite side. The black curtain was then lowered, and the original motivating net floated back to its starting position. On the next trial the second motivating net, now behind the animals, was used to make them return to the original half of the pool. The subjects were gradually familiarized with the apparatus and conditions in several preliminary sessions with the Plexiglas removed and with both apertures free and unoccupied.

During the regular experimental trials, the Plexiglas door was adjusted in position only when the black curtain was submerged and completely covered both of the openings. As in the case of the window experiment, the lateral movement of the Plexiglas from one side to the other was performed in two stages. The Plexiglas was placed in the center position between the two doorways, and it was then given a final adjustment so as to fill one of the openings. In this way the apparatus noise was a two-stage affair and was always the same, even though the Plexiglas was moved away from an aperture and returned to its original position. The right-left sequence of the open doorway upon successive trials was randomly determined.

The timing of a trial began when the curtain was raised and the choice apparatus was exposed to the animals. The timing ended when the animals came up to blow or exhale on the opposite side of the barrier. Since the two porpoises could be readily identified by the observers, time scores were recorded separately for each. If a collision with the Plexiglas occurred, this could at once be detected by the shaking of the net and the angular displacement of the Plexiglas itself.

Data in this experiment were obtained from 50 trials for each animal, or a total of 100 trials for both. The results showed that only two errors were committed in the entire series of 100 trials. The performance, in other words, was 98 per cent accurate. There was also evidence of learning or adaptation, as indicated by a gradual reduction in the time per trial. Underwater sound signals were again present in this experiment, as in the previous ones.

The conclusion seems inescapable that

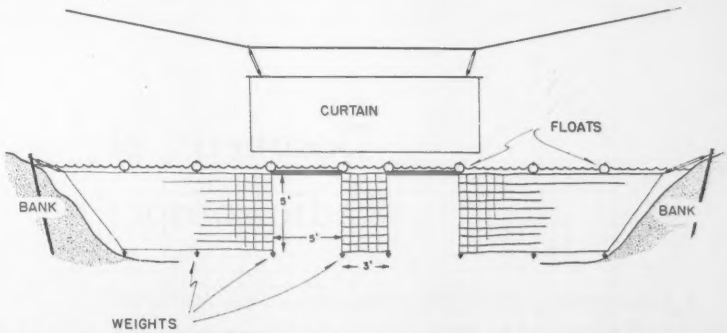

Fig. 5. The plan of the Plexiglas experiment. A steel net or fence was stretched tightly across the porpoise pool beneath the water, dividing it into two sections. The fencing was supported by floats at the surface and was weighted at the bottom. Two openings or doorways (5 feet wide) in the fence permitted the animals to swim from one section of the pool to the other. A heavy sheet of clear Plexiglas was used as a door to block one of the openings. The opaque plastic curtain, manipulated from the bank, could be raised or lowered to cover both openings. When it was raised, exposing the two doorways, this signaled the beginning of a trial. The Plexiglas door was moved from one opening to the other only when the curtain was down, thus concealing the movement.

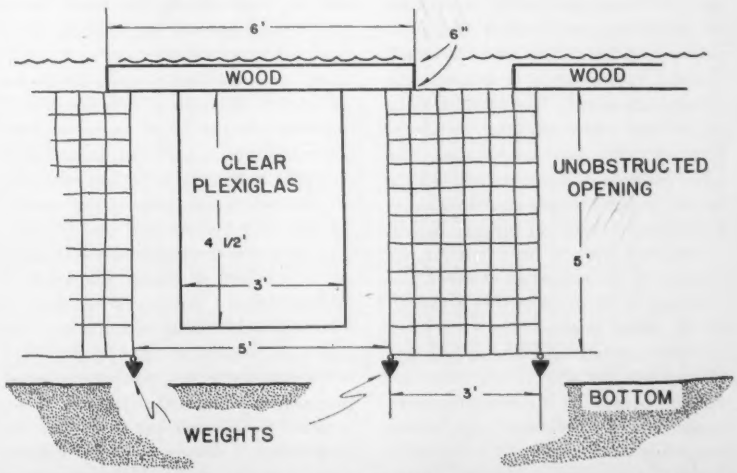

Fig. 6. The Plexiglas door in place in the Plexiglas experiment, whose over-all plan is shown schematically in Fig. 5. The door was moved laterally, by tackle operated from the shore, in such a way as to close or block one opening or the other on any given trial.

the porpoises avoided the solid but invisible Plexiglas door by means of echo ranging. The selection of the open doorway took place, moreover, while the animals were passing through a net of ⅛-inch steel wire, which they also avoided. The location and discrimination of submerged objects by reflected sound signals is without doubt a necessary and a fundamental perceptual avenue for these cetaceans.

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Dosimetry of Radioisotopes

A nomogram permits the estimation of the radiation dose delivered by 30 isotopes of biological interest.

A. J. Bertinchamps and G. C. Cotzias

The statement that radioisotopes are being used with increasing frequency both in biology and in medicine need not be defended here. Indeed the entire problem of irradiation from internally received radioisotopes is assuming increasing importance. Nevertheless, observations are often reported merely in terms of counts per minute or of millicuries without cognizance of whether the isotope provides simply a weak signal or a substantial source of energy. Results so reported are of little quantitative meaning in the evaluation of the degree of change to be anticipated in a biological (or other) system.

A more definitive additional specification, such as the dose rate, is often not reported because of the discouragement caused by the necessary calculations, even when the distortion of a biological system is the primary concern. Therefore, we have developed a simple nomogram (Fig. 1) which permits direct reading of the dose rate for numerous radioisotopes of biological and medical interest (*1*). The use of this device in our center has improved the planning of two types of experiments—namely, tracer as well as radiobiological work. Its use has developed the habit of thinking directly in terms of the forces at work rather than in terms of a partial datum which happens to appear on a luminous dial.

The nomogram permits the reading of beta plus gamma dose rate or either one alone for the center of a cylindrical or of a spherical system. Conversely it aids in choosing isotopes for the delivery of desired dose rates of radiation. The classical dosimetric assumptions (*2*) were employed in constructing it: 1 microcurie is immediately and homogeneously dispersed per kilogram; the system has a density of 1 and behaves like water vis-a-vis irradiation; the entire β-particle energy is absorbed by the system, and the gamma rays have a linear absorption coefficient of 0.03 per centimeter.

The energy due to conversion electrons is included with the β energy; bremstrahlung is neglected, while x-rays due to k capture are not accounted for.

Use of the Nomogram

The formula on which the nomogram is based is the classical one

$$D_{\beta+\gamma} = 51.2\,\overline{E}_{\beta} \cdot n + I_{\gamma} \cdot G \cdot n$$

where $D_{\beta+\gamma}$ is the dose rate in millirad per day at the center of a cylinder or sphere due to β and γ emission; $\overline{E}$ is the average energy in Mev of the beta emission; I_{γ} is the dose rate in rad per microcurie per day at 1 centimeter due to the gamma emission from a point source; G is the geometry factor handling variance in size and shape of the system [its values were calculated from Marinelli, Quimby, and Hine (*3*)]; and n is the concentration of radioactivity in microcuries per kilogram at the onset of the observation.

The beta plus gamma dose rate (per hour or per day) is read as follows.

1) Draw the diagonal corresponding to your isotope on scale A.

2) Choose a cylindrical or spherical model, whichever fits your system best.

3) Draw the vertical from the weight or radius of this model to the diagonal corresponding to your isotope.

4) From the intercept draw a horizontal to scale B.

5) Connect the new intercept on scale

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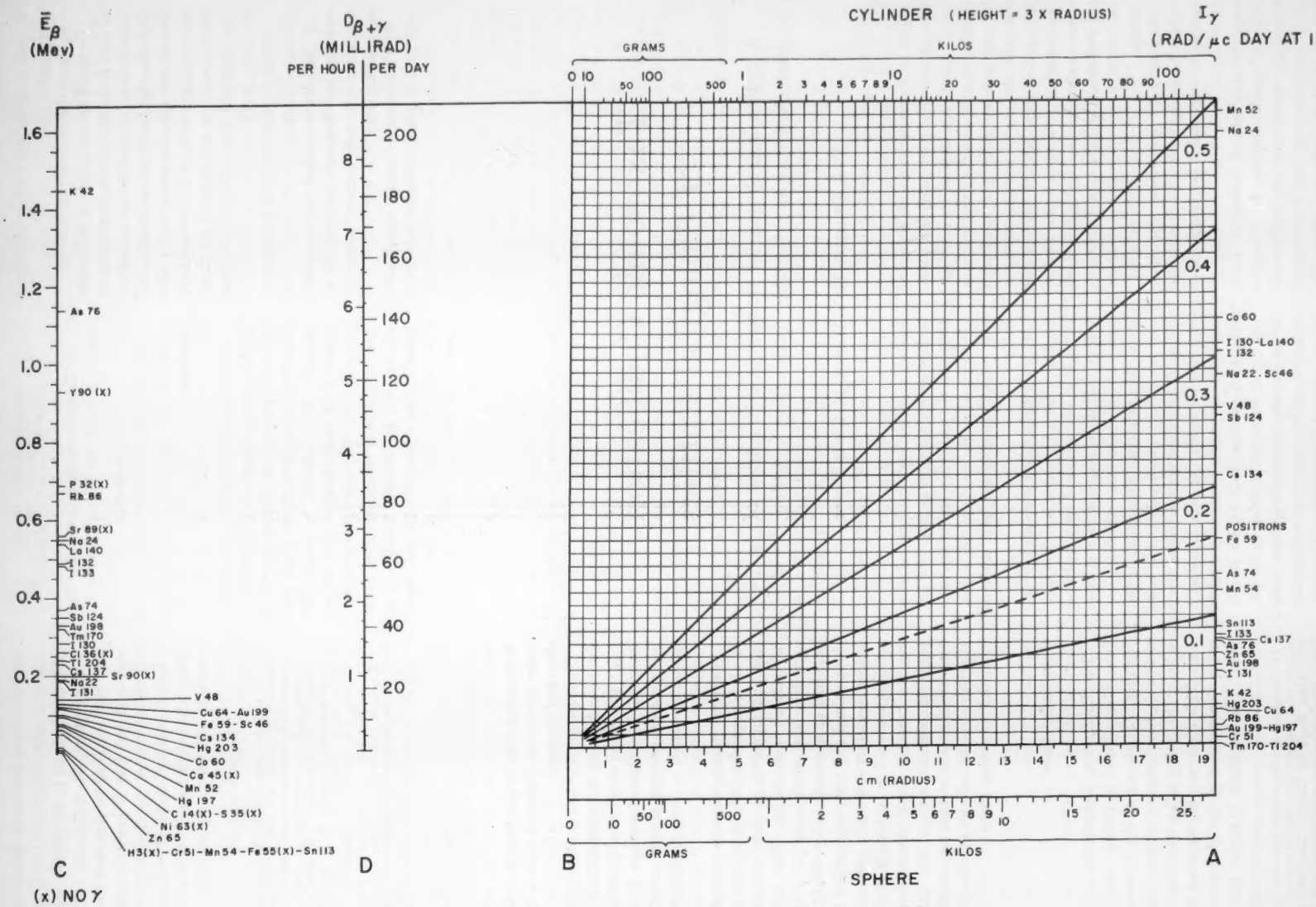

Fig. 1. Nomogram for the radiation dosimetry of internally administered radioisotopes.

B with your isotope on the average β energy scale C.

6) Read the dose rate on scale D.

To read β dose rate only or in the case of pure β emitters use the nomogram as follows. Connect your isotope on scale C with the origin of B (at the intercept of B with the sphere's radius scale) and read dose rate on scale D. To read only the gamma dose rate, connect the intercept on B with the origin of C and read dose rate on D.

Further calculations may be made as follows, if desired.

1) To obtain the dose rate for n microcuries per kilogram, multiply by n, which may be any number larger or smaller than unity.

2) To obtain the "infinite dose," multiply by 1.44 T eff. (effective half-life).

$$T \text{ eff.} = \frac{(\text{physical } T/2) \times (\text{biological } T/2)}{(\text{physical } T/2) + (\text{biological } T/2)}$$

3) To obtain the cumulative dose after time t, multiply the infinite dose by

$$1 - e^{-0.693\, t/T \text{ eff.}}$$

Remarks

The assumptions made in constructing this nomogram should always be kept in mind, particularly in reference to β dosimetry: a highly energetic β ray (for example, K^{42}) will not be totally absorbed in a small volume (for example, a mouse). The unit of time for the dose rate should be chosen very much shorter than the effective half-life. The latter can be estimated with the above formula if the biological decay either follows a single exponential or is negligible as compared to the physical decay. If this is done, this nomogram will not only lead to saving of time and mental wear and tear but, if properly used, it will also minimize the chance of error.

Large working copies of this nomogram, which will be revised if so warranted by new data, are available.

References and Notes

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Taxonomic Codification of Biological Entities

A system is proposed for taxonomic codification of biological entities adaptable to machine handling.

H. A. Denmark, H. V. Weems, Jr., Carlis Taylor

The vast accumulation of biological data presents the ever-increasing problem of filing these data in an easily accessible manner. Since efficient methods of coding quantitative and qualitative data and the use of machine methods have proved their value in business and in the medical profession, it is time that more workers in the biological fields realized the advantages of a well-organized coded system adaptable to machine sorting.

The need for a uniform taxonomic code is becoming more evident with the increasing importance of coordinating work. Some workers are attempting to solve the problem of coding in their fields of special interest. G. Congdon Wood (*1*) compiled an unpublished list of 24 such people in the United States, Canada, England, Italy, and Africa. Of the 24 listed, there are 14 people, representing as many organizations, using a coding system for sorting data. We believe that the code proposed in this article could serve the needs of all biological fields, including our own separate fields.

One of the primary purposes of coding biological information is to facilitate the sorting of mass data by a machine system. The increasing number of subjects to be filed has overtaxed filing systems that use a cross-filing index as the only means of extracting data. The coding of all biological entities would serve as a tool for extracting data and would not affect the present taxonomic nomenclature. A uniform code would permit the rapid exchange of information between organizations, and duplicate cards could be made available to workers interested in coded information. Mass statistical data could be extracted from these coded files by machine in a minimum period of time and with a high degree of accuracy.

Since quantitative and qualitative data can be coded, the first problem is to decide what coding system would best meet the needs of biological workers. A coding system permitting almost unlimited expansion within a category should be selected.

A central clearinghouse for the coding of all biological entities should be created and supported by those interested in such an undertaking. This would necessitate the employment of a full-time staff of specialists, which would include animal and plant taxonomists and trained specialists who would operate the machine system. For uniformity of coding, the proposed clearinghouse should assign all code numbers, and these numbers should be sent to those organizations working with the animals or plants, or both, that are being coded.

Open-Ended Code

The Entomology Department of the State Plant Board of Florida and the Statistical Laboratory of the University of Florida have adopted an open-ended code for the coding of all biological entities. This code may be described best as an "open-ended group classification code." The taxonomic coding of biolog-

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ical categories being coded by the State Plant Board of Florida are kingdom, phylum, class, order, family, genus, and species. Any number of categories may be included in this system of open-ended coding, but the categories and the number of digits for expansion must be determined in advance. In addition to the taxonomic coding of all biological entities, the location, scientific name of specimen, stage of specimen, host, date collected, collector, degree of infestation, weather, determiners of insects or other invertebrates and their hosts, treatment of specimen, and location of specimen, if preserved, also are coded by the Plant Board.

One digit is provided for kingdom, two digits are provided for phylum, two digits for class, two digits for order, three digits for family, three digits for genus, and three digits for species. Up to 9 different items can be coded for each unit, 99 for two units, 999 items for three units, and so on. For example, the three units allotted for species will permit the coding of up to 999 species in any one genus; this allows for greater numbers of items in any one of these categories than would ever be needed.

Taxonomic entities are being coded at random rather than phylogenetically or alphabetically because of the simplicity of adding names to a coded list. Random assignment of code numbers does not cause entities to become regimented, nor does it necessitate the reassignment of code numbers when names are added, as would be the case if the names were coded alphabetically or phylogenetically. The code number remains with a scientific name, even though the name is placed in synonymy. If the synonym should prove to be a valid species it will have a code number. Thus, for example, in order to select all filed data on a particular species of insect, one would machine-sort all cards for the code number of that species and also for the code numbers of all synonyms under which data have been filed at any time. This, of course, requires the maintenance of species files, including synonyms, as in any other system of filing data relating to plants or animals. To put it more simply, code numbers are merely substituted for words so that data can be filed compactly and sorted by machine.

Clearinghouse

Coding should be done by the proposed clearinghouse and should not be the responsibility of the separate organizations. This would require the close cooperation of all taxonomic workers, with each sending all proposed name changes to this central clearinghouse for coding once the names have been approved, or a literature abstracting organization could relay names of newly described species to the clearinghouse for coding.

The State Plant Board is the clearinghouse for the State Plant Pest Survey, which is a state and federal cooperative project. Several thousand insect indentifications are made each year. Weekly and annual summaries of the insect conditions are being compiled. The laborious task of hand-sorting these data would require hundreds of hours of secretarial time, and errors are often introduced in the course of transcribing. Data coded for machine-sorting reduce the time required to extract information and reduce the possibility of errors to a minimum. The files of detail cards have been arranged alphabetically by class, order, family, genus, and species. Two cards have been developed for filing data. One card is designed to handle all in-state reports and is red-striped along the top margin; a second card is designed for all out-of-state and foreign reports and is blue-striped along the top margin for ease of visually separating the two types of cards. The change by the Plant Board from a three-way file (specimen, host, and accession number) on 3- by 9-inch cards to a one-card file on an I.B.M. card has reduced the necessary filing space by several dozens of linear feet.

Table 1. Coded data compiled by the State Plant Board of Florida.

Homoptera	Cicadellidae	*Hortensia*	*similis* (Walker)
04	004	010	001

Machine Installation

The Plant Board, as a matter of convenience, is using the services of an I.B.M. punched-card system that is located on the campus of the University of Florida. Many organizations may not have sufficient work to justify a machine installation. The Plant Board does not have machines at this time but plans to install a key-punch machine and a sorting machine. If an organization should consider the use of some or all of the necessary equipment, it would be advisable to adopt coding for as many phases of its work as possible to defray the operating expenses of these machines. The Plant Board is presently coding a Plant Pest Survey, a Citrus Tree Count Survey, and all the invertebrates collected by the Quarantine Department of the State Plant Board at the ports of entry. The machine may be used, also, for inventories and payrolls.

An organization need not be located near a machine installation. A small organization can keep a detail card file in its office and send coded information to a machine installation that will contract to punch, sort, and summarize data periodically. As an example, the information received from the State Plant Board field inspectors and from Florida Agricultural Experiment Stations, Florida Agricultural Extension Service, commercial companies, and private citizens is coded by the Plant Board. Once the reporting form has been received and the determination of the specimen has been made, the form is rechecked for the correct scientific names. All information is coded on an 80-column code sheet and sent to the University of Florida Statistical Laboratory. A detail card is filed in the office of the Entomology Department for a ready reference of individual reports. Longer reports are summarized by the Statistical Laboratory.

The Plant Board has coded data assembled over a period of 4½ years at the time of writing of this article.

Some of the special features of handling coded data are as follows:

1) If an insect has been positively coded to genus and doubtfully to species, it is possible to indicate the doubtful determination in coded data by overpunching at the point that is doubtful.

2) The disposition code indicates that a specimen has been discarded or pinned, placed in a preservative, stored in an envelope, mounted on a slide, embedded in plastic, photographed, or whatever the case may be. The collection in which the specimen is located may be indicated, also.

3) Parentheses around an author's name are indicated by an ampersand before and after the name, since some machines are not equipped with parenthesis keys.

An example of an insect and its code, selected from the Plant Board's coded data to show the function of the code, is given in Table 1.

The code indicates the 4th order, the 4th family within the 4th order, the 10th

genus within the 4th family, and the 1st species within the 10th genus. The code is quite flexible, and, when proper expansion is provided for, the system will allow for coding of an almost infinite number of entities.

Conclusion

The State Plant Board of Florida has adopted an open-ended code for coding biological entities. The system permits the coding of quantitative and qualitative data and the sorting by machine of mass data with a high degree of accuracy. Although the form used by the Plant Board is designed primarily for surveys, the coding by other organizations of animals and plants should be made uniform to increase the usefulness of the code on a world-wide basis, regardless of the form used. Uniform coding can be accomplished best through a central clearinghouse.

On casual consideration this system may appear to be expensive and complicated. Actually, however, the coding procedure is relatively simple. Careful examination of the total cost of cataloging, extracting, and analyzing data and the comparative ease of performing the operations that are described in this article shows the system to be economical.

If the idea of standardizing is accepted by biologists, it might result in our being able to compare results better and in expediting the obtaining of information pertaining to such subjects as life histories, populations, and distribution.

Note

1. Dr. Wood is head of the Biology Group of the Chemical-Biological Coordination Center, Washington, D.C.

News of Science

Antarctic Research Program at U.S. Stations Resumes after Polar Winter

The onset of the antarctic spring signaled the resumption of a heavy schedule of International Geophysical Year scientific activities in Antarctica. After long months of polar darkness, the 70 scientists who wintered over at the seven United States IGY stations have accelerated work in a broad range of geophysical missions. Many of them have moved from winter quarters into the field.

Study Subjects

Antarctica's structure beneath its thick coating of ice, the frigid region's effect on world weather and climate, its influence on global communications, its geologic history and geophysical future, are among the subjects in the scientific study of this vast land area. The all-out scientific effort also includes accumulation of significant data on aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, meteorology, and seismology. Shipboard rocketry experiments and oceanographic research, as well as special station studies in botany, zoology, and microbiology, will be conducted.

Traverses

Much of the scientific information to be collected by U.S. scientists in the coming season as the IGY nears its end will be gathered on a series of major oversnow traverses (see map on page 993). The surface traverse parties, moving in tractors fitted with electronic apparatus for detection of crevasses, will conduct seismic, glaciological, and other geophysical studies. One traverse departed from Little America Station about 15 October in an attempt to cross the Ross Ice Shelf to the top of the Skelton Glacier and continue to Victoria Land Plateau. Another traverse will start 1 November from Byrd Station in Marie Byrd Land, covering the territory between the station and the Horlick Mountains, skirting the northern edge of the Horlick Mountain Range for a distance of 200 to 300 miles, and then returning to Byrd Station. A third traverse will pick up from Ellsworth Station, near the Weddell Sea coast, and continue on to Byrd Station. The traverse parties use seismic techniques to measure ice thickness and to determine the character of the subglacial floor and of exposed land areas.

Besides the oversnow treks, an airborne traverse is planned. This will follow a course running southward from Mount Waesche to the northern edge of the Horlick Mountains. The study group, traveling in ski-equipped planes, will land at 50-mile intervals for seismographic soundings probing the depth of the antarctic ice sheet. It will also engage in gravity observations and glaciological work.

Personnel

Scientific leaders at the U.S. IGY antarctic stations are: Little America Station, Albert P. Crary; Byrd Station, Stephen S. Barnes; Wilkes Station, Willis L. Tressler; Ellsworth Station, Matthew J. Brennan. At Hallett Station, a joint United States–New Zealand undertaking, the scientific leader is a New Zealander, K. J. Salmon. Recently, the study group which wintered over at the various stations was augmented by some 70 additional colleagues who were transported to Antarctica for summer-season research. Some of the newcomers will remain for the next winter, relieving current IGY personnel.

Past Work

IGY scientists in Antarctica have already collected much significant information:

Seismic measurements of ice thickness indicate that there is probably 40 percent more ice in Antarctica than was previously thought. Scientists from the Byrd Station, for example, measured ice 14,000 feet thick, resting on bedrock 8200 feet below sea level; this may be the thickest ice measured anywhere in the world.

The antarctic ice covering is estimated to have been, at one time, as much as 1000 feet thicker than it is now. Not yet known, however, is whether the total ice mass is presently increasing or decreasing.

A record low temperature of – 125.3°F was reported by Soviet scientists at an IGY station near the center of Antarctica. At the South Pole itself, U.S. IGY radiation studies have shown that during the antarctic midsummer the pole receives more sunlight than any other

place on earth. But up to 95 percent of this radiation is reflected by the ice cover, leaving the pole one of the coldest spots in the world.

United States IGY traverse parties discovered a new mountain range, and a deep underwater trough running from a point 35 miles east of Ellsworth Station and averaging 3500 feet below sea level.

Deep drilling operations, which at Byrd Station already have reached more than 1000 feet into the ice, have brought up cores of ice which fell as snow over 1000 years ago. These operations will be continued at Little America. Analysis of the ice cores is expected to add greatly to knowledge of past climates.

The U.S. IGY effort in Antarctica is supported logistically by the Navy's Task Force 43, commanded by Rear Admiral George Dufek. The task force assignment, a continuation of a massive job begun under Dufek's leadership in 1955, carries the code name Operation Deep Freeze IV.

Future Plans

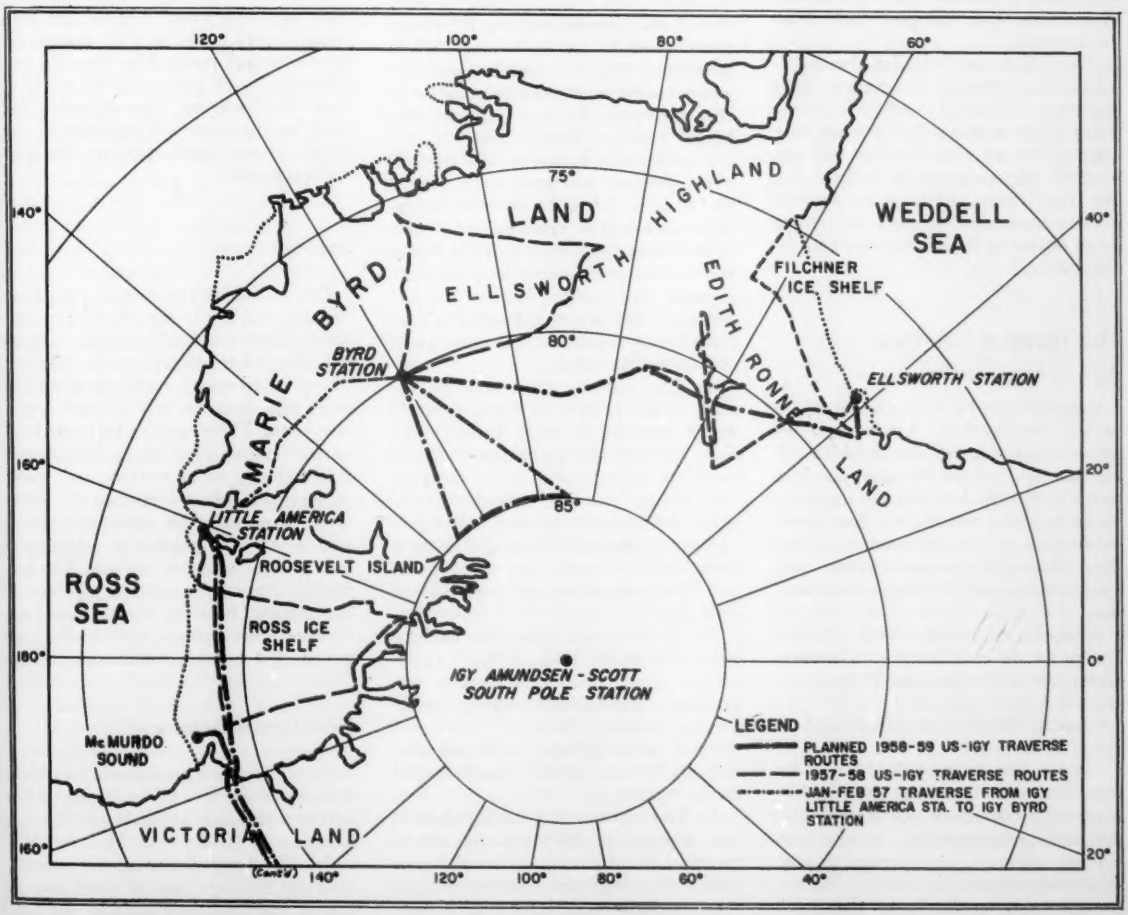
Upon conclusion of the International Geophysical Year, 31 December, U.S. scientific activity in Antarctica will be conducted by the National Science Foundation in cooperation with the National Academy of Sciences' Committee on Polar Research. Four U.S. stations are to remain in operation when the IGY ends. They are the Amundsen-Scott South Pole Station, located at the geographic bottom of the world; the Naval Air Facility at McMurdo Sound; Byrd Station; and Hallett Station on Cape Hallett in the Ross Sea, supported jointly by the United States and New Zealand.

Eleven other nations are carrying on scientific programs in the Antarctic as part of the IGY. They are Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, the Union of South Africa, the U.S.S.R., and the United Kingdom. Custody of the Ellsworth Station is to be taken over by Argentina, and Australia is to take supervision of Wilkes Station on the Knox Coast.

Solar Eclipse

On 12 October 1958 the sun was totally obscured by the moon for observers along a narrow strip of the earth's surface beginning at dawn in the South Pacific east of New Guinea and extending eastward some 9000 miles to sunset at the west coast of South America. Near the midway point along this strip, a few hundred miles south of Tahiti, the maximum duration of totality occurred: 5 minutes and 12 seconds. This was a longer-than-average period of totality; the maximum possible duration is 7 minutes and 31 seconds.

The narrow path of totality, up to 124 miles wide, was almost entirely over water. It touched, in addition to the western part of South America, only eight small land areas—islands or island



Major oversnow traverse routes which will have been covered by the end of United States participation in the Antarctic Program of the International Geophysical Year (see page 992).

groups—in the South Pacific. Among these were the Danger Islands in the Cook group.

American observing groups selected as their site Motu Koe, the southernmost of the three Danger Islands and the one closest to the center of the path of totality. Transportation and logistic support for the observers were supplied by the Department of Defense. The Navy furnished a vessel, the LSD *U.S.S. Thomaston,* both to transport scientists and equipment and to serve as a base of operations.

The Eclipse and The IGY

This unusually long eclipse was of particular importance because of its occurrence during the International Geophysical Year. The scheduling of the IGY from July 1957, to December 1958, was intended to coincide with a peak period in the cycle of sunspot activity. Solar eruptions during such periods are followed by many observable effects on the earth and its atmosphere, such as cosmic ray storms, auroral displays, disturbances in the ionosphere, magnetic fluctuations, and disrupted radio communications.

The eclipse also afforded the opportunity to coordinate observations of a variety of terrestrial conditions, by the many widely scattered IGY stations, with observations of solar features and terrestrial effects during an eclipse. For the first time, high-altitude research rockets were used to study the effects of an eclipse on the stratosphere and the ionosphere.

First Details of New Space Agency Organization

Appointments to the top management of the new National Aeronautics and Space Administration were announced 5 October by T. Keith Glennan, administrator of NASA. Initially, the organizational structure provides for three principal areas of activity—namely, space flight development, aeronautical and space research, and business administration.

Reporting to the office of the administrator are the directors of each of these areas: Abe Silverstein, John W. Crowley, Jr., and Albert F. Siepert.

Glennan described the NASA organization as follows:

"In the first category, NASA will be concerned with the entire spectrum of space flight operations including the design and procurement of vehicles and satellite payloads, the launching and monitoring of scientific satellites, the accumulation and reduction of data, and activities supporting the objective of launching man into space.

"In the second category, the long-established and highly regarded laboratories acquired from the NACA will continue their programs of basic and applied research in support of aeronautics and space science and technology. Additional effort in this area of activity will be supported in the laboratories of industry and educational and non-profit institutions.

"The third category, business administration, includes the business functions of any well-run organization, such as the development of fiscal and budgetary policies, of contracting policies and their implementation, of policies relating to personnel administration, plant operation and security, and the provision of administrative policy guidance for the decentralized operation of NASA's research centers and field stations."

Proposed Institute for Study of Man in Africa

When at the end of 1958 Raymond A. Dart retires from the chair of anatomy at the University of the Witwatersrand, which he has held since 1923, it is planned that his work be continued and extended by the establishment of an Institute for the Medical and Anthropological Study of Man in Africa.

A group of past and present students and colleagues of Dart have conceived the idea of the institute, the purpose of which would be to advance the study of the living peoples of Africa in health and disease and to serve as a museum, research, and teaching center. The objectives of the proposed institute are set forth by the organizing committee in its constitution as follows:

1) The institute shall advance the study of the peoples of Africa today in health and disease, their bodily structure, function and pathology, diet and nutrition, genetics and racial composition, disease patterns, climatic adaptations, demography, physical anthropology, psychological problems and cultures, including art, music, languages, social and tribal structure, and psycho-social attitudes.

2) In the second place, the institute shall advance the study of man's ancestors in Africa, their fossil remains, migrations, hybridizations, climatic background, associated flora and fauna, and cultures, including implements and other cultural objects, artistic creations and burial customs.

3) The institute shall foster and facilitate research in the laboratory and in the field; provide educational facilities, both intra-mural and extra-mural; set up a museum of Africana, which shall serve as a repository for collections within the University of the Witwatersrand bearing on the subject of man in Africa, past and present; build up a library and set up a centre for the collection, classification and dissemination of information on all relevant aspects of man in Africa.

Africa's need for workers in all of these fields is great, and it is expected that one great service which such an institute would fulfil, would be to draw young men and women into such work and to train competent personnel for field-work up and down the continent. Another important aim should be to provide adequate facilities for, and encouragement to, visiting scientists from overseas to spend periods working on African material.

Dart's record has included the deanship of the Medical Faculty in Johannesburg from 1925 to 1943, membership on the board of the South African Institute for Medical Research from 1934 to 1948 and on the Medical Advisory Committee of the Council for Scientific and Industrial Research from 1946 to 1948. He has served as president of the South African Association for the Advancement of Science and received the association's gold medal in 1939. Among his greatest achievements have been his contributions to all aspects of the study of man in Africa, not least of which has been his discovery and appraisal of the South African fossil ape-men, the Australopithecinae.

Seawolf

On 6 October the atomic submarine *Seawolf* surfaced off New London, Conn., after a record-breaking continuous submersion which lasted for 60 days. The previous record, set by the *Seawolf's* sister ship *Nautilus,* was 31 days and a few hours. The *Seawolf's* feat was held to have significance for a number of fields, chiefly naval warfare and space exploration. Admiral Hyman G. Rickover, commenting on the performance, said it was now possible to establish a hidden base beneath the sea. For the field of astronautics, with its problem of the extended isolation of space travelers, the experience of the crew of the *Seawolf* is expected to have considerable value.

New Atomic Reactor

A prototype of a nuclear reactor which is designed for space-vehicle propulsion will be tested soon at an Atomic Energy Commission facility near Mercury, Nevada. The basic design of the reactor calls for the injection of gases into a fission reaction, their sudden and extreme heating by it, and their expulsion through directing nozzles for propulsion.

So little is known about the actual performance of this radical design that elaborate safety precautions are being employed in the pretest preparations. A two-mile railroad track will carry the reactor from the engineering center to the instruments that will test its performance. It will then be returned to the engineering center for further examination.

As an additional safety precaution, the test center itself is laid out in the form of a triangle, with the test bunker, the engineering center, and the control center placed at the three angles. A distance of two miles separates each unit from the adjacent units.

Radioactivity Catalog

A world-wide search has been launched to locate at least 2000 persons who were exposed to radium poisoning during the period 1920–1930.

A program initiated by the Massachusetts Institute of Technology looks toward the establishment of a central catalog agency which would serve as a major source of information on the effects of radioelements in the body. The search is primarily directed toward locating persons who were exposed to radium either in connection with their work (for example, the painting of luminous watch dials) or as a part of medical treatment.

The central catalog, to be set up at the Radioactivity Center of the institute, will record information on persons who have carried radioactive material in their bodies for a generation or more. All physicians have been requested to aid in the search, which is being conducted with the cooperation of the division of biology and medicine of the Atomic Energy Commission.

Uranium Isotopic Standards

The National Bureau of Standards, in cooperation with the Atomic Energy Commission, has prepared the first of a series of uranium isotopic standards for use by educational and research institutions and industry in the United States and abroad. Ten standard uranium isotopic samples became available from the bureau on 1 October 1958. Five additional uranium standards are in preparation to complete a series of fifteen.

Standards for other atomic energy materials such as plutonium and thorium will be made available under a continuing program intended to provide materials of known certified composition which will be universally acceptable as analytical standards.

Order forms for domestic use (AEC contractors and licensees) may be obtained from the National Bureau of Standards, Washington 25, D.C. Orders from foreign sources should be submitted to the Division of International Affairs, U.S. Atomic Energy Commission, Washington 25, D.C.

New Detector for Infrared Radiation

Scientists at the Westinghouse Research Laboratories have developed a new infrared detector. The device, so sensitive that it can respond to less than 0.05×10^{-9} watt of infrared (heat) radiation, was developed by Max Garbuny, J. R. Hansen, and T. P. Vogl, in consultation with Henry Levinstein of Syracuse University.

Every object above the absolute zero temperature of outer space emits infrared radiation, which is generated inside the molecules of a material as a result of their own thermal motion. The higher the temperature, the faster the molecules move, and the more energetic and shorter in wavelength is the infrared radiation emitted by the body. The infrared wavelengths lie between the wavelengths of visible light and microwaves.

The function of an infrared detector is to convert infrared radiation into electrical signals that can be amplified and seen. It is the "heart," as well as the most critical component, of complete infrared systems, which are assuming ever-increasing importance in a variety of scientific and military tasks. These systems are used for guiding missiles to a target, for detecting missiles and fast-flying aircraft, for making "heat pictures" of the ground in the complete absence of light, for studying the radiation from stars and other celestial bodies, and for a variety of similar purposes. The detector is potentially very useful in medical research, astronomy, exact scientific experimentation and industrial control.

Since the sensitivity and frequency response of a photoconductive infrared detector are increased by operating it at low temperatures, the new detector is cooled to a temperature of −320°F by surrounding it with liquid nitrogen in a special container.

Grants, Fellowships, and Awards

Mathematics. The School of Mathematics of the Institute for Advanced Study will allocate a small number of grants-in-aid to gifted young mathematicians and theoretical physicists to enable them to study and to do research work at Princeton during the academic year 1959–60. Candidates must have given evidence of ability in research comparable at least with that expected for the degree of doctor of philosophy. Blanks for application may be obtained from the School of Mathematics, Institute for Advanced Study, Princeton, N.J., and are returnable by *1 January 1959*.

Medicine and dentistry. The University of Rochester has established a program of postdoctoral fellowships to be awarded graduates of approved medical schools to enable them to pursue research in any of the departments of the School of Medicine and Dentistry. The Buswell fellowships are intended to assist well-qualified doctors of medicine to prepare adequately for academic careers. Junior fellowships will be awarded to medical graduates who have completed at least 1 year of internship or equivalent training. Research experience is not required but will be of advantage. Research interest and promise are essential. Stipends range from $4500 to $6000 per year. Senior fellowships will be awarded to medical graduates who have held a junior fellowship for 2 or 3 years or have had comparable experience in medical research and wish to continue in an academic career. Stipends range from $5500 to $8000 per year.

Applications for Buswell fellowships will be received at any time. Additional information and application forms may be obtained from Dr. L. E. Young, Chairman, Committee on Buswell Fellowships, University of Rochester Medical Center, 260 Crittenden Boulevard, Rochester 20, N.Y.

News Briefs

A major oceanographic research program for the Indian Ocean is being prepared by the Special Committee on Oceanographic Research of the International Council of Scientific Unions. The study, to take place during the period 1961–62, will be an international effort with scientists from the United States, the Soviet Union, the countries bordering the Indian Ocean, and others participating. Among the problems to be studied will be the mass mortality of fish, the ocean's floor, and the effect of monsoon winds on the currents and layers of the ocean. A fleet of at least 16 research ships is expected to be used in the program. A total cost of $4 million is the current estimate for the year-long program.

* * *

The more than 600 technical papers presented by American nuclear scientists at the second International United Nations Conference on Peaceful Uses of Atomic Energy held in Geneva 1–13 September have been published by the Atomic Energy Commission and are for sale by the Office of Technical Services.

U.S. Department of Commerce, Washington 25, D.C. A list of the papers may be obtained from OTS for 25 cents.

* * *

The name of the University of Pennsylvania's School of Auxiliary Medical Services has been changed to the School of Allied Medical Professions. The academic programs at the school offer bachelor of science degrees in physical therapy, occupational therapy, oral hygiene, and medical technology. The school also offers certificates in physical therapy and occupational therapy to graduate students who have received their bachelor's degrees.

* * *

In an Air Force demonstration last month a Bomarc missile "destroyed" a 1000-mile-an-hour target missile. Although both missiles were launched at the Cape Canaveral test center, the Bomarc was under fire control by a SAGE air defense network center at Kingston, N.Y., 1500 miles away. The target missile was flying 75 miles away from the test center at an altitude of 4800 feet. The "knock-down" was simulated—recorded by an instrument—and the target missile later crashed near the cape landing strip.

* * *

The National Science Foundation has announced that 642 grants totaling $12,162,513 were awarded during the quarter ending 30 June 1958 for the support of basic research in the sciences, for conferences in support of science, for exchange of scientific information, and for training of science teachers. This is the fourth group of awards to be made during fiscal year 1958. During the first three quarters, awards totaled approximately $25.2 million.

Scientists in the News

Sir RUDOLPH PETERS, a biochemist of Babraham College, Cambridge University, was elected president of the International Council of Scientific Unions at the closing meeting of that body's general assembly in Washington. W. A. ENGLEHARDT of the Academy of Sciences of the U.S.S.R. and PERE LEJAY of France were elected vice presidents. NICOLAI HERLOFSON of the Royal Institute of Technology, Stockholm, Sweden, became secretary-general, and E. HERBAYS of Belgium was reelected treasurer.

The American Institute of Electrical Engineers' Medal in Electrical Engineering has been awarded to J. F. CALVERT of the University of Pittsburgh, "in recognition of his distinguished service as a teacher of electrical engineering and as evidence of the high esteem in which his contributions are held by his fellow members of the American Institute of Electrical Engineers." Calvert, who is head of his university's electrical engineering department, will be presented the medal on 27 October during the opening session of the institute's 5-day fall general meeting at Pittsburgh.

The four winners of the American Heart Association's 1958 Howard W. Blakeslee Awards are as follows:

EUGENE J. TAYLOR, science writer, the *New York Times,* for a series of four articles which explained the nature and effects of cerebrovascular accidents, or strokes. The articles were published 28 through 30 November 1957.

LEE GEIST, management editor, *Business Week,* for his article, "Must Cardiacs Go on the Shelf?," which surveyed the attitudes of business and the medical profession regarding the employment of persons who have suffered a heart attack. The article was published on 8 June 1957.

"Hemo the Magnificent," television film, illustrating the function of the heart and the circulation of the blood, produced by Frank Capra as one of the Bell System Science Series and broadcast over the CBS–TV network on 20 March 1957.

"Stroke," a live-television program broadcast on 27 April 1957 which showed how stroke victims can be helped by early rehabilitation in the hospital and in the home. The program was part of the "Medical Horizons" series sponsored by Ciba Pharmaceutical Products, Inc.

JAMES J. STOKER, JR., associate director of New York University's Institute of Mathematical Sciences, has been named director of the institute. He succeeds RICHARD COURANT, who retired on 31 August. Courant is now professor emeritus of mathematics and science adviser to the university.

Scientific visitors to the United States from the United Kingdom include the following.

R. GOLDSMITH, a member of the Medical Research Council's scientific staff at the National Institute for Medical Research, Division of Human Physiology, London, is spending 6 to 8 weeks (which began early in September) in the department of pathobiology, Johns Hopkins University. Following his visit there, he will join a research party that is to be sent to the Antarctic for about 7 months.

D. W. GREEN, member of the Medical Research Council's external staff at Davy Faraday Research Laboratory, Royal Institution, London, will spend a year with Rich at the Massachusetts Institute of Technology.

J. MANDELSTAM of the bacterial physiology division, National Institute for Medical Research, London, has been granted leave of absence for a year to take up a research fellowship in the department of bacteriology at the Harvard Medical School from 1 October till 31 January 1959, and to work with Holvorson at the University of Wisconsin from 1 February till 30 September 1959.

ROBERT E. WOODSON, JR., professor of botany at Washington University, has been appointed curator of the herbarium of the Missouri Botanical Garden.

HENRY W. RIECKEN, JR., professor of sociology at the University of Minnesota, has been appointed program director for social science research at the National Science Foundation. He replaces HARRY ALPERT, who has accepted a position as dean of the Graduate School, University of Oregon.

JOSEPH SIMON, formerly of the University of Wisconsin, has been appointed associate research professor in the Cancer Research Laboratory of the University of Florida. He is in charge of the section on experimental pathology.

JOHN S. HALL became director of the Lowell Observatory on 1 September. For the past 10 years Hall was director of the Astrometry and Astrophysics Division of the U.S. Naval Observatory.

CLAUDE E. SHANNON has been appointed to be the first Donner professor of science at Massachusetts Institute of Technology. The chair was established recently with a grant of $500,000 from the Donner Foundation of Philadelphia.

JOHN L. FULLER, senior staff scientist at the Roscoe B. Jackson Memorial Laboratory, has been appointed assistant director for training at that institution. Effective 1 October, Fuller will direct all educational programs at the Jackson Memorial Laboratory. These include training courses for students at all levels, from precollege through postdoctoral grade.

ELWOOD R. QUESADA, lieutenant general, U.S. Air Force (ret.), has been appointed by President Eisenhower to head the newly established Federal Aviation Agency. He had been the President's special assistant on aviation matters.

E. LENDELL COCKRUM, associate professor of zoology at the University of Arizona, has been appointed research associate in the department of mammals of the American Museum of Natural History in New York.

Book Reviews

A History of Technology. vol. III. *From the Renaissance to the Industrial Revolution, c. 1500–c. 1750.* Charles Singer, E. J. Holmyard, A. R. Hall, Trevor I. Williams, Eds. Clarendon Press, Oxford, England, 1957 (order from Oxford Universtiy Press, New York). xxxvii + 766 pp. Illus. + plates. $26.90.

With the appearance of this, the third of five proposed volumes relating a history of technology to the beginning of the 20th century, readers of the first two volumes should carefully reread the earlier prefaces. For as this monumental project creeps ever closer to modern times, it becomes abundantly clear, as the editors had warned, that the extreme selectivity necessary even in five bulky volumes precludes all possibility of an ideal, definitive history. In the preface to volume II the editors wrote, "When completed, this *History* will provide a moderately comprehensive survey of the development of western technology." I feel that it is very important for all readers of these volumes, especially of the later ones, to realize that this statement reflects no false modesty on the part of the editors, but rather reflects their serious awareness of the dilemmas inherent to their undertaking.

Two difficulties are especially apparent in this third volume and will no doubt be felt even more keenly in the succeeding volumes. First, there is the anomaly in the historian's art whereby the "definiteness" of a historical picture is sometimes related by inverse proportion to the amount of available data. If one writes about, say, astronomical instruments in antiquity, where the amount of extant information is all too finite, the problem of creating a history of such instrumentation may be one of gathering even enough information to make meaningful statements. But, on the other hand, in such a case it is at least possible to accurately and exhaustively treat the available data and to make more or less plausible conjectures on the basis of them, and in this limited sense one might call such history definitive. The opposite extreme occurs when the historian must either catalog a near-infinite amount of data or attempt the type of value judgments involved in selecting "representative" data. Obviously the problem has a time dimension: in the vast majority of cases, the nearer history comes to the present, the greater the amount of available data, and hence the problem of digestion or indigestion.

One might recall here two recent examples of historians who directly faced this problem. When the late George Sarton regretfully ended his labors on his great *Introduction to the History of Science* (Williams and Wilkins, 1927–48), he found that it had taken almost as many pages to deal with the 14th century alone as with the entire period from Homer to Roger Bacon. It was his considered view that no one scholar working alone could hope to continue the project on such a scale, due to the sheer enormity of the data bearing on science in later centuries. Lynn Thorndike's half-century odyssey in the preparation of a *History of Magic and Experimental Science* (Columbia University Press, 1923–58) led him to similar conclusions, with the result that he has ended his history with the 17th century.

In the present case, the editors have been determined not to bog down in the Middle Ages but to face the problem by being "highly selective in their choice of topics for discussion, and have perforce imposed on authors restrictions of space that have rendered their tasks far from easy." Thus, we shall have a "moderately comprehensive survey," carrying the story down to our own century, through the process of choosing what appear at this time to be crucial or at least typical technological developments.

The second difficulty is not unrelated to the first. It is simply the fact that the historian synthesizing the story of our more recent technological past must do so with the benefit of far fewer detailed monographic studies. The reasons for this are perhaps not hard to find. The long tradition of classical and medieval studies, again with the seeming benefit of there being comparatively limited data for analysis, has encouraged the production of monographic studies of ancient technology. This is apparent in the earlier volumes of the present work, where, for example, the learned scholar R. J. Forbes essentially summarizes portions of his life's work of detailed study of ancient science and technology. Unfortunately the ground has not as yet been spaded very deeply in many areas of technology from the Renaissance to the present. This may result, I feel, in an unevenness in the real evidence behind the conclusions reached in this study, both in terms of areas of technological activity within a given time period and also from volume to volume representing different time periods. It might also result in an unwary reader assuming that the articles in the later volumes have an authoritativeness which the authors themsleves would hesitate to claim.

As an example of the need for further monographic studies before a survey of this sort is completely feasible, we might look at page 345 of A. P. Usher's otherwise splended article "Machines and mechanisms." This section was certainly written before he was acquainted with the *History of the Gear Cutting Machine*, one of the series of monographs undertaken by my colleague Robert S. Woodbury to provide the scholarly basis for his history of tools. In the light of Woodbury's evidence, the last two paragraphs of this section (as I am sure Usher would be the first to admit) need complete revision.

The clock- and watchmakers were in only a very few cases interested in scientifically correct shapes for their gear teeth, and even those who knew the theoretical results, such as Thomas Reid of Edinburgh, felt the design of such teeth to be too complex to be worth the trouble. In any case, the results of the mathematicians' work were generally published in Latin and often appeared in erudite scientific journals unknown to clockmakers. Thiout made no new contributions to the theory at all and only reprinted Camus' paper of 1733. Although Camus' work began in 1733 and not in 1735, it certainly was far less important than the analysis of de La Hire, upon which Camus admitted he had based his own contributions. Actually, the theory of gear teeth was not in a form which practical men could use before the appearance of John Issac Hawkins' *Teeth of Wheels* (London, 1806), although there were a number of rule-of-thumb handbooks, such as Jacob Leupold's *Theatrum machinarum generale* (Leipzig, 1724).

Woodbury also shows in detail, in an article to appear in an early issue of *Isis*, that Desargues, and not Roemer or de La Hire, was the first to advocate epicycloidal teeth for gears, probably as early as 1644–49. Huygens never claimed to have orginated this theory and gave the credit both to Roemer and to Desargues.

The men who developed the mathematical theory of gear teeth were, if anything, more interested in improving efficiency and reducing wear in gearing for various types of mills than for clocks. To be sure, the theory had little effect in industrial practice until after Hawkins (in 1806) and Willis (in 1841), but neither were the machine tools and the knowledge for precision and complexity

"fully worked out on this small scale" of clocks and watches in the early 18th century. Yet Polhem's gear-cutting machine dates from 1729, and Rehe's gear-cutting machine, first described in 1783, had probably been used for cutting wheels for the silk-reeling works built by Boulton about 1780 for the East India Company. The gears for Rennie's Albion Mill (built during the period 1784–88) had epicycloidal teeth carefully chipped and filed to shape.

In short, the very able scholars who wrote the articles in this volume in many cases simply do not have—because they do not exist—the adequate monographic studies on which to build a scholarly history of technology.

Nevertheless, it would be worse than invidious were I not to point out the excellent qualities everywhere apparent in this difficult-to-write volume. It is organized into five parts, essentially matching the divisions of volume II, each of which contains numerous articles with short but useful bibliographies. As in the preceding volumes, the illustrations are accurate and germane, and the plates at the end of the volume are nothing short of magnificent. The reader will at once realize that much thought and searching has gone into the selection of the illustrative material, so important in conceiving of the history of man's relation with material things and objects. Perhaps the dominant theme throughout the work—or at least the notion most strongly reinforced for me—is that during these fertile two and one-half centuries, the period of the scientific revolution, what we often call pure science affected technology very little. This was still a craftsman's age, despite the tremendous conceptual upheaval that attended the downfall of scholasticism and the birth of modern science. Repeatedly our authors conclude that science, as we know it, began seriously to instigate technological changes only at the end of the 18th and beginning of the 19th centuries. This is perhaps a truism to which everyone would agree, but the authors in this project can do a great service by teaching us more of the details of this transition. For this and similar reasons we anxiously await the concluding volumes.

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Ionographie. Les émulsions nucléaires. Pierre Demers. University of Montreal Press, Montreal, Canada, 1958. 835 pp. + plates. Illus. $20.

Ionographie (which deals with the self-inscription of the path of fast charged nuclear particles traversing photographic emulsions) can be said to be the first comprehensive work on this important tool of modern nuclear physics. The title selected for this monumental work by Pierre Demers is perhaps apocalyptical, in view of the disturbing and restless age we are living in—"The Moving Finger writes; and, having writ,/ Moves on." In the English-speaking world the subject is usually referred to as nuclear emulsions, in an effort to differentiate the specially tailored photographic emulsions useful in the recording and discrimination of the tracks produced by the diverse fast-moving nuclear particles from the more common optical emulsions.

That alpha particles produced individual tracks in fine-grained emulsions, readily resolvable with the aid of the microscope, was known on the Continent as early as 1909. The technique, however, did not gain favor with experimentalists in the field of radioactive measurements until after the discovery of the neutron. This massive uncharged projectile racing through an emulsion will collide with the hydrogen nuclei of the gelatin and, at a given angle of incidence, will impart enough kinetic energy to the ionized nucleus so that it records a "proton-recoil track" in the recording medium.

The emulsion became an important competitor with the Wilson cloud chamber as a means of visualizing the path of charged particles during the early days of the Manhattan Project, when it became necessary to discriminate and elucidate the properties of the newly discovered fission fragments from the alpha particles emitted in the spontaneous decay of the uranium isotopes. Demers, as a member of the Canadian group, was particularly active in this field and was able to demonstrate, with the aid of his improved laboratory-made emulsions, that the normal binary fission process also occurred in an alternate mode, in which a high-energy alpha particle accompanied the two massive fragments originating from the neutron splitting of the uranium atom. Demer's researches on the preparation of concentrated emulsions containing as much as 90 percent of silver bromide, by weight, stimulated interest in the large-scale industrial manufacture of early nuclear emulsions such as the Eastman NTA plate and the Ilford series of B, C, D, and E plates.

The ready availability of these new recording media at the end of World War II led to a series of revolutionary discoveries by cosmic-ray workers, which in turn have altered our picture of nuclear structure. This simple tool led to the discovery of the pi mesons, the heavy primary component of the cosmic radiation, trident formation in the electromagnetic cascade, and the production of heavy "strange particles" in high-energy interactions. More recently it proved instrumental in elucidating the mode of annihilation of the antiproton and demonstrating lack of conservation of parity in π-μ-e decay processes.

This new volume, of virtually encyclopedic proportions, not only is concerned with the preparation and development of nuclear emulsions but also presents a lucid description of almost all applications in the field of nuclear physics and radiochemistry. Over 100 pages are devoted to a bibliography covering several thousand entries, with cross reference to points in the text where the subject matter is discussed. In general, the style of writing is reminiscent of Mellor's *Comprehensive Treatise on Inorganic Chemistry,* in which an effort is made to cover the literature completely. The bibliography appears to be complete to 1957, and Demers must have made considerable effort to extend his work even when it was in galley form, as some of the more important current papers of 1958 are also listed.

The first section of *Ionographie* is devoted to the manufacture of nuclear emulsions on a laboratory scale. While most readers will probably not attempt to "roll their own," a knowledge of the factors governing sensitivity will be helpful in understanding the shortcomings of commercially available products. This section of the book also describes the new Russian type P emulsions, which achieve a grain density of 60 per 100 microns of track produced by singly charged relativistic particles at the minimum of ionization. This is some three or four times greater than the sensitivity currently available in emulsions of American or British manufacture.

The volume covers the methods of normal and discriminatory development of both plates and stripped emulsions up to 600 microns in thickness. A more thorough treatment of specialized techniques permitting the processing of 2-millimeter-thick slabs would have been a useful addition to the book. Needless to say, the diverse ailments inherent in the technique—such as fading of the latent image, track distortion, gelatin blistering, and surface silver image corrosion—are given detailed treatment. A large section is devoted to the geometrical problems of plate exposure and evaluation of results. As an indication of the thoroughness of the treatment, even ancillary techniques, the details of which are often difficult to locate in the literature, are described in detail. Thus, the cosmic-ray worker will find methods for the measurement of atmospheric depth, details on the fabrication and launching of balloons, and meteorological data on wind directions for facilitating the recovery of the emulsion stacks. Demers can write authoritatively on these matters as he performed these operations in the field.

Physicists will find this volume useful in making range-energy measurements, evaluating particle momentum by multiple scattering techniques, and making charge identification by grain and delta-ray counting. The theory and systematics of alpha decay processes are considered in great detail, together with quantitative theory on the formation of alpha stars in emulsion. The evaluation of neutron energy spectra is particularly thorough. About one-third of this scholarly work is devoted to applications of the nuclear emulsions in high-energy physics, both with collimated beams of particles from accelerators and in the study of the cosmic radiation. By comparison, coverage of other types of applications, such as that in the fields of geology and histoautoradiography, while adequate in view of general principles developed in earlier sections, may appear scanty, occupying only 13 pages of fine-printed text.

In an age where individual scientists take pride in being expert on some small facet of nature, it is exhilarating to find a comprehensive work covering a broad vista of science skillfully integrated by a single mind. Demers is to be congratulated for his arduous efforts in providing a greatly needed, authoritative work on the use of photographic emulsions in nuclear physics.

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Effect of Radiation on Human Heredity. Report of a study group convened by the World Health Organization, together with papers presented by various members of the group. World Health Organization, Geneva, 1957 (order from Columbia University Press, New York). 168 pp. Illus. $4.

The purpose of the study group whose report is presented in this volume was, according to the preface, twofold: (i) to obtain the opinions of authorities on genetics from countries other than Great Britain and the United States, whose national committees on radiation hazards reported in 1956; and (ii) to probe certain untouched aspects of the problem of genetic hazards, especially "the lines of research which should be followed, in the light of our present knowledge, to increase our understanding of the genetic effects of ionizing radiations on man." At the meeting of the first International Congress of Human Genetics in Copenhagen during August 1956, a group of 20 highly expert investigators in various aspects of human genetics was assembled. The report actually comprises only ten pages of the volume, and while it will undoubtedly stimulate some research to bring about the solution of critical problems and to supply key information, and while it may serve to increase financial support of research in human and other branches of genetics, this section is hardly the most valuable or interesting part of the book. It is hard not to mimic those generals who are forever fighting the last war.

The volume contains a collection of a dozen papers, however, every one of which is worth reading and rereading. The happy juxtaposition of the first two papers (by H. J. Muller and T. C. Carter, respectively) spotlights one of the most controversial matters in genetics today—one that is related to the whole problem of estimating genetic damage and hazard. This is the problem of the frequency of deleterious mutant genes that are always, or almost always, harmful no matter what the conditions, in comparison with the frequency of mutant genes that are seriously detrimental only when present in a person in double dose (homozygous) and which, when present in single dose (heterozygous), may, at least under certain conditions, be selectively advantageous. If the first situation predominates, then most mutant genes are held in the population in simple equilibrium between input (mutation) and outflow (elimination through failure to be passed on because of death or infertility). But if the second situation obtains, the interplay of forces is far more complex and consequently less predictable. Muller adopts the former view; Carter, and after him Wallace, the latter.

R. M. Sievert, of Sweden, gives a masterly summary of known human exposures to ionizing radiation. One may note the fact that he had no premonition of the recently discovered zone of extremely heavy radiation at high altitudes, for the curves drawn in 1956 all flatten out at about 50,000 feet. The Swedish data in general are in good agreement with the conclusions of the British and American committees. J. Lejeune discusses the kinds of data needed and the practicability of detecting induced mutations in the offspring of radiated parents. There is wide misapprehension on this subject. Lejeune is properly cautious. Court Brown describes methods being developed for more accurately determining the genetically all-important gonad dose delivered by various types of exposure.

Measurement of the spontaneous mutation rate in man by direct and indirect methods, the effects of induced mutations, the differential sensitivity of human loci to radiation, and the load of abnormal genes per person in the population are topics discussed by L. S. Penrose. There follows the first report of the radiation readings in inhabited areas with particularly high background radiation, such as the region of monazite sands in Travancore. Gopal-Ayengar reports readings that are high, but hardly as high as rumor had previously made them. He estimates a total gamma dose of about 10 to 30 roentgens over the reproductive span of 30 years in that locality. The world will be understandably interested in the prompt investigation of the populations living on such soils. Is their genetic burden detectably higher than that of similar populations not so exposed to radiation?

Stevenson and Neel probe the difficulties and possibilities of error in estimating spontaneous mutation rates in human populations. Freire-Maia considers the effect of inbreeding in bringing more mutant recessive genes to the surface and exposing them more rapidly to selection. The frequency of genetic defect *manifested* in a population is *not* a simple function of the frequency of the genetically defective genes. Howard Newcombe, of Canada, completes the series of papers by describing the sort of vast genetic health registration of the population that is really needed if many of these problems are to be solved.

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Electronic Instrumentation for the Behavioral Sciences. Clinton C. Brown and Rayford T. Saucer. Thomas, Springfield, Ill., 1958. xiv + 160 pp. Illus. $5.50.

In 160 pages this book provides "a simplified presentation of basic electronic theory required for instrumentation problems." The volume is specifically oriented toward fields of experimental psychiatry, psychophysiology, and physiology where electronic instrumentation is required for stimulation or measurement.

The first chapter offers a brief, lucid discussion of the physical theory underlying electronic phenomena, followed by an elementary review of methods of electrical measurement. Tube types and basic circuitry are next considered. This section is followed by chapters on power supplies, amplifiers, oscillators, timing devices, and switching circuits. Valuable suggestions are made regarding input and output transducers, including devices for tracing and displaying physiological changes. There is commendable emphasis on various methods for the protection of human subjects of experimentation. A chapter is devoted to test instruments, with suggestions regarding kits available for their economical construction. Recommendations are made regarding specific instruments that are

commercially available. Unfortunately, such limited citations, which occur throughout the book, do not survey the field of acceptable available equipment. A notable omission concerns the highly successful employment of vibrator (chopper) type amplifiers for high-sensitivity, drift-free recording of small direct current potentials.

A virtue of this book is its conciseness, and it would be unfair to enumerate all the things that might have been included. Under the heading of recording devices, for example, one might wish for mention of the enormously important role to be played in the near future by frequency-modulated tape-recording of physiological variables. Tape-recording provides the present possibility of instrumental reproduction and review, rerecording, and reanalysis and the eventual possibility even of automatic measurement and tabulation.

Preceding the final chapter on the laboratory workshop is one which is especially valuable at the present stage of electronic development—on transistor theory, transistor types, and comparison of transistor with vacuum tube circuitry. Recommendations are made regarding useful, currently available transistor types.

The book is what it purports to be and can be recommended as a useful, simplified, brief presentation of basic electronic theory and its application to psychophysiological problems.

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A Handbook of Lattice Spacings and Structures of Metals and Alloys. W. B. Pearson. Pergamon Press, New York and London, 1958. x + 1044 pp. Illus. $38.

In 1912 von Laue discovered the diffraction of x-rays by crystals. This was immediately applied by the Braggs to the elucidation of the atomic arrangements in solid matter. However, it was not until the early 1920's that the new technique was sufficiently developed for large-scale application to the study of metals. For this development thanks are largely due to the pioneer work of Arne Westgren and of A. J. Bradley. As a result of their work the x-ray diffraction technique now takes its place alongside the classical thermal and microscopic methods as an essential tool in metallurgical research, an important aspect of which is the determination of thermal equilibrium diagrams.

The book under review is largely concerned with the enormous developments in alloy structure determinations and phase diagram studies which have taken place since those early days. It is truly encyclopedic in character. Its coverage of the vast literature which has grown up since those early days—much of it scattered and buried in obscure papers—is astonishingly complete, and the condensation of this literature into usable form in the space of a single volume is a truly remarkable achievement. The book will prove an indispensable vade mecum for the metallurgist and will be of invaluable service to the solid-state physicist.

Among the most useful features of the book is the long table of intermediate phases, which includes some 4000 compositions. Comprehensive as it is, I noted at least 30 omissions; among these may be mentioned Fe_3Mo_2, $MoBe_{13}$, MnZn, Mn_3Sn_2, InMg, Fe_3Ti, and $MgZn_5$. I feel that the lattice spacings should have been uniformly given in absolute angstrom units. The table provided on page 257 for the conversion of kX to angstrom units is not very helpful and could have been omitted.

The discussion of lattice parameter determinations would have been greatly clarified if a diagram illustrating the various film arrangements for the powder diagrams had been given. A discussion of modern powder diffractometry, with its special advantages, would have been appropriate here.

The real meat of the book is given in chapters 11 and 12. Here we have 640 pages of detailed, well-coordinated, accurate, and excellently illustrated data on the lattice parameters of alloys, metal carbides, borides, and nitrides, along with details concerning their purity, preparation, heat treatment, and equilibrium structures. These two chapters represent a real tour de force and will save the reader countless hours of literature searching. The text, comprehensive as it is, needs to be supplemented with phase diagrams. Could room be made for them in the next edition?

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Plant Design and Economics for Chemical Engineers. Max S. Peters. McGraw-Hill, New York, 1958. xi + 511 pp. Illus. $11.

This book by Max Peters is the latest addition to the literature directed towards the economics of chemical engineering. The objective of this volume is to present economic and design principles as applied to chemical engineering processes and operations. The early chapters develop the principles of applied economics, covering such topics as interest, investment costs, depreciation, taxes, and cost accounting. For the most part, the remainder of the book discusses equipment design and costs in considerable detail.

The attempt to treat so broad a subject in one volume has resulted in scanty coverage of such topics as waste disposals, patents, and equipment fabrication. Numerous problems are included at the end of most chapters, and there are some major design problems.

The book is intended for the advanced student as well as the practicing engineer; it should prove to be of greater value to the student.

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Einführung in die Messtechnik der Kernstrahlung und die Anwendung der Radioisotope. Heinrich Fassbender. Thieme, Stuttgart, 1958. 223 pp. $8.85.

This book presents in five chapters a clear and compendious introduction to radioisotope techniques. Emphasis is on the German development (about 65 of the 75 references deal with German publications). Thus, the book provides an interesting reflection on the present status of German science in this important field and, at the same time, is useful to the student.

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New Books

The Absorption of Infrared Radiation. Robert P. Bauman. McGraw-Hill, New York, 1958. 551 pp. $8.90.

The Academic Marketplace. Theodore Caplow and Reece J. McGee. Basic Books, New York, 1958. 272 pp. $4.95.

The Background of Astronomy. Henry C. King. Braziller, New York, 1958. 254 pp. $5.

Principles and Applications of Random Noise Theory. Julius S. Bendat. Wiley, New York, 1958. 452 pp. $11.

Reticular Formation of the Brain. A symposium sponsored by the Henry Ford Hospital, Detroit, Michigan, and held at the hospital 14–16 March 1957. Herbert H. Jasper, Lorne D. Proctor, Robert S. Knighton, William C. Noshay, Russell T. Costello, Eds. Little, Brown, Boston, 1958. 780 pp. $16.

Vistas in Astronautics. First annual Air Force Office of Scientific Research Astronautics Symposium. Morton Alperin and Marvin Stern, Eds. Pergamon, New York and London, 1958. 351 pp. $15.

The Waking Brain. H. W. Magoun. Thomas, Springfield, Ill., 1958. 146 pp. $4.75.

Reports

Some Principles of Self-Contained Underwater Breathing Apparatus

With the increasing use of self-contained underwater breathing apparatus in archeological collection work, geological and petroleum prospecting, and biological collecting, diving equipment has taken on real importance as a scientific tool. Numerous techniques have evolved to make diving units easier to breathe from so that divers can make longer work or exploratory dives and so that neophytes will be less likely to suffer lung fatigue. This report (*1*) presents a brief résumé of some of the principles of existing apparatus along with concepts leading to more advanced forms. The principal emphasis is on "open circuit" equipment in which air is inspired from a high-pressure tank and expired into the surrounding water. In such cases the compressed air is also an energy source, which allows incorporation of certain forms of regenerative feedback leading to easier breathing.

Such equipment uses a regulator which feeds the diver air at a pressure just equal to that of the surrounding water. In essence, a regulator is a box with a flexible side which activates an internal valve. If the air pressure within this box is reduced to below that of the surrounding water, then the valve will be opened by the diaphragm, thus allowing air from the high-pressure cylinder to enter the box, until the equality of internal and external pressure is returned. Through a hose, the diver breathes from this box. When he exhales, his breath travels through the other hose attached to the mouthpiece or mask and out through a one-way valve which is positioned close to the diaphragm. If the outlet (for example, a "Bronx cheer") is ½ in. from the diaphragm, then the tension in the valve is set so that slightly more than ½ in. of water vacuum must be produced in the diver's mouth before air will be fed, or else, in some diving positions, air will spontaneously stream from the regulator and out through the exit valve. Other factors being the same, single-stage regulators tend to breathe more easily, while two-stage regulators tend to give more uniform breathing difficulty as the tank pressure drops.

If a small collapsible bag is attached to this air system, then as one breathes out, a few hundred cubic centimeters of the breath are saved and will be the first air to be inspired on the succeeding breath, of which it makes up only a fraction of the total (the rest being supplied by the regulator). Some of the early observations on such a method should be credited to C. Lambertson. The advantage to be obtained by such a partial rebreathing process in practice is not simple to predict and seems to decrease with active work.

If one builds a unit from which it is easy to breathe on land, one will still inevitably find that there is an appreciable amount of work required to draw in a breath when one is below the surface of the water and in the usual face-down position. Because the diaphragm is then situated above one's lungs, the air that one must inspire is at a slightly lower pressure than the average water pressure on the lungs. When a diver is on his back the pressure differential is in the opposite sense, and one's lungs have no greater strength to work against such pressure differentials, so the strain is again appreciable. Most people have little concept of the relative weakness of their breathing apparatus compared with typical small hydrostatic forces (*2*). One can effectively locate the regulator within the lungs and obtain normal equally easy breathing in all positions by loading the diaphragm of the last-stage regulator with a suitable weight (Fig. 1). This weight must supply a force to the diaphragm that a column of water extending between the diaphragm and the center of the chest will exert. A diaphragm-sized weight's thickness is thus approximately half the chest thickness divided by the specific gravity of the weight material. The weight can be supported by the linkage and then, depending on whether the weight pushes or pulls on the diaphragm, the regulator must face toward or away from the person; the direction it faces will be reversed if the regulator is worn on the chest rather than upon the back. If a regulator is oriented so that the weight's line of motion passes through the center of the lungs, then it can be compensated though fixed to some part of the body other than the center of the back. Such a unit allows perfectly free inspiration under all conditions, but in one set of positions the effort in exhaling will be as difficult as it is with an uncompensated unit. Voiding the air into a lower-pressure reservoir such as a branched arrangement of tubes pointing in several directions, each with a one-way valve at its far end, can do away with even this slight inconvenience. The effect of separation of regulator and outlet valve by this procedure can be overcome by making the outlet slave-controlled by diaphragm motion, besides having its normal one-way action. There can then be no leakage of air or water in any position. A closed circuit (rebreather) unit can be similarly compensated with a weight, and in this case there is no outlet valve. Questions of hunting because of the extra mass included in the feedback loop, or of difficulty in obtaining a sudden breath because of diaphragm inertia, prove experimentally unfounded in a reasonable design.

The action of a regulator can be im-

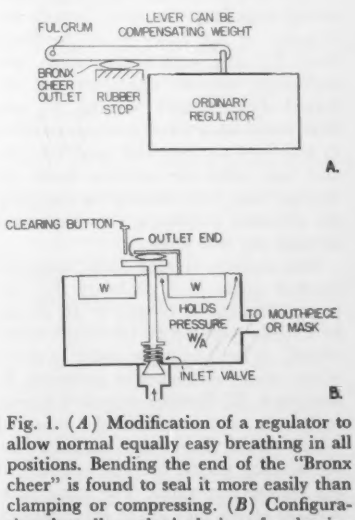

Fig. 1. (*A*) Modification of a regulator to allow normal equally easy breathing in all positions. Bending the end of the "Bronx cheer" is found to seal it more easily than clamping or compressing. (*B*) Configuration that allows the inclusion of a clearing button to expel water accidentally entering the unit, and which insures that one valve will close before the other opens. A lever is not needed if the area of the outlet is considerably less than that of the diaphragm.

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper. (Since this requirement has only recently gone into effect, not all reports that are now being published as yet observe it.)

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

proved by positive feedback which brings about increased air flow by the act of starting to pass air. If the feedback factor is made high enough so that the loop gain in this system is greater than or equal to unity, then the system will become bistable (*3*)—that is, a small suck will bring about a self-perpetuating air flow that will persist until back pressure builds up. No effort is involved in breathing in the intermediate condition. Limited positive feedback makes breathing easier, but the use of hysteresis or bistability requires further experiment to determine whether, due to nonlinearity in muscle response, it may not take more work to start and stop a self-perpetuating flow than to produce a steady vacuum in the usual fashion. However, human muscles do seem to be able to give a short intense effort more readily than a weaker prolonged one. Methods of producing the bistability (feeding air or not feeding air) include constructing the diaphragm in the fashion of an oil-can bottom, spring-loading the linkage as in a toggle switch, shaping the valve seat so that opening gives an increasing area to produce an increased opening force, or the use of a Venturi tube in which air flow reduces the pressure applied to the diaphragm, thus sucking it in. By analogy with the generation of a nerve impulse, or the action of monostable multivibrator, one can visualize another type of unit in which a bistable regulator is returned after a short interval to its original off state by some auxiliary process such as a slow leak into the main chamber from the high pressure region.

Breathing can be made easier by eliminating impedance to flow through the inclusion of the hoses in the feedback loop. For any such configuration two essentially isolated chambers are involved. For example, sucking, via one hose, could cause the diaphragm to move in and feed air into and from the second hose until the pressure backs up through both. One exhales into and from the chamber containing the diaphragm through the first hose.

One problem of deep diving might be touched upon. It is necessary that the partial pressure of oxygen at all depths be roughly within a factor of ten above normal at the surface in order to avoid either oxygen deficiency or poisoning. In discussion, M. Bradner suggested storing oxygen in a hemoglobin-like material which would always then maintain the surrounding partial pressure constant at the equilibrium value. The extra pressure, to match that in the surroundings, would be supplied through a regulator by a high-pressure cylinder of helium or nitrogen which would have to supply gas only during descent, and thus could be small. Alternatively, a mixed-gas apparatus could either receive oxygen from a pressure-insensitive, constant-flow-rate device, or else an oxygen-detecting element could be used to control the flow. For a detector, for example, one might employ the output voltage of a fuel cell (*4*). H. Bradner has suggested that oxygen content might be controlled by the mechanical changes in size of certain chelates or else by the output voltage of any oxygen-depolarized battery. Alternatively, one could control oxygen flow by monitoring the generation of carbon dioxide.

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References and Notes

1. This work was supported in part by a grant from the Schussler Fund. The weight-compensated regulator was previously described in *Seafarer* [1, No. 2, 3 (1954)].
2. R. S. Mackay, *Am. J. Phys.* **16**, 186 (1948).
3. ———, *ibid.* **26**, 60 (1958); *J. Appl. Phys.* **25**, 424 (1954).
4. *Chem. and Eng. News* 35, No. 38, 25 (1957).

15 September 1958

Preservation of Whole Blood in Frozen State for Transfusion

Abstract. Addition of sugars to whole citrated human blood permits freezing and thawing with recovery of a large percentage of erythrocytes. Survival of erythrocytes thus frozen, transfused without further modification after thawing, has been satisfactory after 6 months of storage at −93°C.

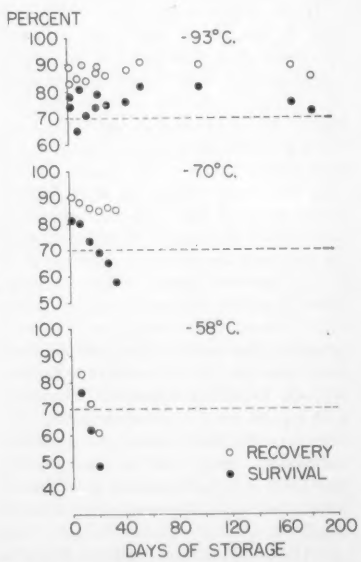

Fig. 1. Effect of temperature of storage on recovery and survival of frozen human erythrocytes. Each solid circle represents a transfusion.

Hemolysis due to freezing of erythrocytes at temperatures below −3°C (*1*), followed by thawing, may be avoided to a considerable extent by ultra rapid freezing (*2*) or by modification of freezing with the addition of glycerol (*3*).

In the study described in this report (*4*) modification of erythrocytes to prevent hemolysis has been obtained with varying concentrations of dextrose and lactose, alone or in combination. Modification consists in mixing equal parts of acid-citrated blood with the sugar solution to obtain a 0.2*M* concentration of lactose, a 0.7*M* concentration of dextrose, or an additive molarity of 0.6 with both sugars. The length of modification is not critical, and periods of 5 to 270 minutes have given similar results.

Modified blood is frozen in flat containers made of thin aluminum or tin-plated copper, measuring inside 3 mm in thickness, by immersion, in CO_2–ethanol mixture at −60 to −78°C. Thawing is obtained by immersion in a water bath at 37°C. Optimally the time of cooling and freezing, from −3° to −40°C, and the time of thawing must not exceed 10 seconds.

The results of freezing and thawing of erythrocytes will be expressed as "recovery" and "survival." By "recovery" is meant the number of intact red cells remaining after freezing and thawing; "survival" indicates the amount of radioactivity of frozen, stored, thawed, and transfused red cells remaining in circulation in the recipient 24 hours after transfusion, as determined with the Cr^{51} tagging technique. The values reported as survival include all losses occurring in vitro and in vivo. Blood has been transfused within 1 hour of thawing, without any further preparation.

Without use of sugars the recovery of human erythrocytes frozen and thawed with the technique described averages 29.3 percent. With the modification of freezing obtained with sugars the average recovery rate is optimally about 95 percent. The 24-hour survival of erythrocytes in five transfusions of human whole blood frozen and thawed without appreciable period of storage is only 2 percent below the optimal established for fresh, autotransfused erythrocytes; the curve of disappearance of erythrocytes after the first 24 hours parallels that of fresh cells.

The recovery and posttransfusion survival of erythrocytes of whole blood frozen as described and stored in the frozen state depend on the temperature of storage. With storage at −58°C, both rate of recovery and rate of survival deteriorate rapidly, as shown in four transfusions (see Fig. 1). At −70°C, the rate of recovery is fairly well maintained for about 40 days, but the survival in six transfusions deteriorates progressively

and at 3 weeks is already below 70 percent. At −93° ± 2°C a satisfactory recovery and survival are maintained for periods of at least 6 months, as shown in 13 transfusions.

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21 July 1958

Ionium-Thorium Chronology in Deep-Sea Sediments of the Pacific

Abstract. The ratio of ionium to thorium varies exponentially with depths in deepsea sediments of the Pacific Ocean and gives rates of accumulation of the order of millimeters per thousand of years. Surface values of the ratio were not constant over the eastern Pacific Ocean. This observation may result from differences in thorium isotope concentrations in near bottom waters which furnish these isotopes to the sediments.

The method of ionium-thorium chronology (*1*) of deep-sea sediments is based on the simultaneous removal of ionium (Th^{230}, $t_{1/2} = 80{,}000$ years, a member of the U^{238} radioactive series) and thorium (Th^{232}, $t_{1/2} = 1.4 \times 10^{10}$ years) from the water to one or more of the mineral components of the deposits. The critical assumptions for the application of the method follow. (i) The Io/Th ratio has remained constant in the waters adjacent to the sediments over the time intervals involved. (ii) The chemical species of Io and Th in the sea water are the same, and these isotopes have identical distributions among them. (iii) The analyzed materials do not contain detrital materials, of continental or volcanic origin, with significant contributions of Io or Th. This method appears preferable to the previous method of radium chronology (*2*) inasmuch as the observed diffusion of radium from the decay site of its parent ionium can invalidate any age determinations (*3*).

Table 1. Ionium-thorium ratios in three cores from the Eastern Pacific Ocean (Capricorn 50BG—latitude 14° 55′N, longitude 124° 12′W, 4270 m; Chinook 11—latitude 49° 39.5′N, longitude 177° 39′W, 4850 m; Downwind 49HG—latitude 42° 02′S, longitude 98° 01′W, 4350 m). The ratios are given in terms of disintegrations of Io per disintegration of Th per unit time.

Depth interval in core (cm)	Io/Th ratios		
	Capricorn 50BG	Chinook 11	Downwind 49HG
0–4	30	16	35
4–8	23	18	26
8–12	16	11	19
12–16	9.0	10	5
16–20	8.4	7.0	2
20–24	6.1	6.2	
24–28	5.3	4.4	

The isotopes of Th were isolated from sediment samples by previously described methods (*4*) and subsequently plated on a 1-in. platinum disc. Preferential solution of the nondetrital matter was accomplished with hot, concentrated hydrochloric acid. The principal detrital minerals, quartz and feldspars, were insoluble and were discarded following centrifugation. The recovery of the Th isotopes from the samples was determined with UX_1 (Th^{234}), and yields varied between 50 and 98 percent. The plated Io and Th were readily differentiated and quantitatively assayed with an alpha-ray spectrometer, a Frisch screen-grid ion chamber being used as a detector. The dominant alpha energies of Io and Th are 4.6–4.7 and 3.98, respectively (*5*).

Preliminary analyses (*6*) of a number of Eastern Pacific deep-sea cores have emphasized three significant results. First of all, exponential decreases in the ratio with depth have been observed in 10 of the 12 cores analyzed. Two South Pacific cores had values of the ratio that were both low and essentially invariant with depth. Whether such results indicate a lack of deposition over the last few hundred thousand years or a loss or disturbance of the upper section of the core during the handling has as yet not been determined. Table 1 gives typical analyses on three cores collected by expeditions of the Scripps Institution of Oceanography.

Secondly, determinations of the recent rates of accumulation of these Eastern Pacific clays, made on the basis of these data and of the half-life of ionium, are remarkably uniform, with values for the Capricorn, Chinook, and Downwind cores of 1, 2, and 1 mm per 1000 years, respectively, in the upper 10 cm. A dramatic drop in the Io/Th ratio, corresponding to nearly 2 half-lives of ionium over a few centimeters' distance, is observed in the Downwind core. Such a change has been observed in but one other core, also from these southerly latitudes.

Finally, *the surface ratios* fall into two distinct groups: a set in the region between the Aleutian Islands and Hawaii with values averaging about 15 and a second group, in the region between longitude 120° and 140°W and latitude 40°N and 40°S, with a ratio varying around 35. The cores given in Table 1 are representative of such groups. The isotopes of lead show a similar distribution pattern (*7*).

These results can be interpreted on the basis of the assumption that the deep-oceanic water masses, which are in contact with the sediment surfaces, furnish these isotopes to the sediments. Hence, these two regions should have circulating, overlying water masses which possess values for the Io/Th ratio which are similar to those found in the surface layers of the sediment deposits. The distinctive isotopic composition of thorium in a given water mass probably reflects the weathering processes responsible for the introduction of thorium and uranium into the water mass and the inorganic and biochemical processes in the ocean that cause their removal.

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18 June 1958

Radio Control of Ventricular Contraction in Experimental Heart Block

Abstract. This report describes a method for the stimulation of the ventricular myocardium by transmitting the stimulus over a radio-frequency carrier which is demodulated by a radio receiver enclosed within the animal's chest. The method can be applied in conjunction with experimental heart block.

Experimental heart block combined with electrical stimulation of the myocardium is a valuable technique in the study of the physiology and the pathology of the circulatory system.

Heart block can be created surgically, in dogs, with fairly uniform success and maintained for prolonged periods (*1*). In such animals the ventricular myocardium can be stimulated electrically for as long as 10 days, without serious injury. This procedure provides the means for driving the ventricles at various rates and for studying the relations between such ventricular rates and other variables in the circulatory system.

Folkman and Watkins have recently stimulated the ventricular myocardium, in dogs, by amplifying the pulses originating in the auricles with an external amplifier and using the output of the latter for stimulation (*2*).

The electrical stimulation used so far, in this kind of experiment, was provided by various types of electronic pulse generators connected *by wire* to the myocardium, the wires reaching the heart after passing through the thoracic wall. This required maintaining an opening in the skin and in the muscles during the investigative period, with constant danger of infection and considerable discomfort and limitation of movement for the animal.

Because of these disadvantages of connection by wire, an attempt has been made, in this laboratory, to stimulate the ventricular myocardium remotely, without any wires running from the stimulator to the animal. This was achieved by transmitting the stimulating pulses via an RF carrier and demodulating this carrier, within the animal's chest, by means of a suitably miniaturized receiver.

The experimental arrangement is shown in Fig. 1. A conventional 200-watt radio transmitter is electronically "keyed" at the desired frequency by means of a pulse generator and a keying system operating on the grid of the final RF amplifier. A transmission line takes the pulsed RF carrier so generated to a loop antenna placed underneath the cage in which the animal is kept, a strong RF field being thus generated inside the cage. The receiver is located within the thoracic wall.

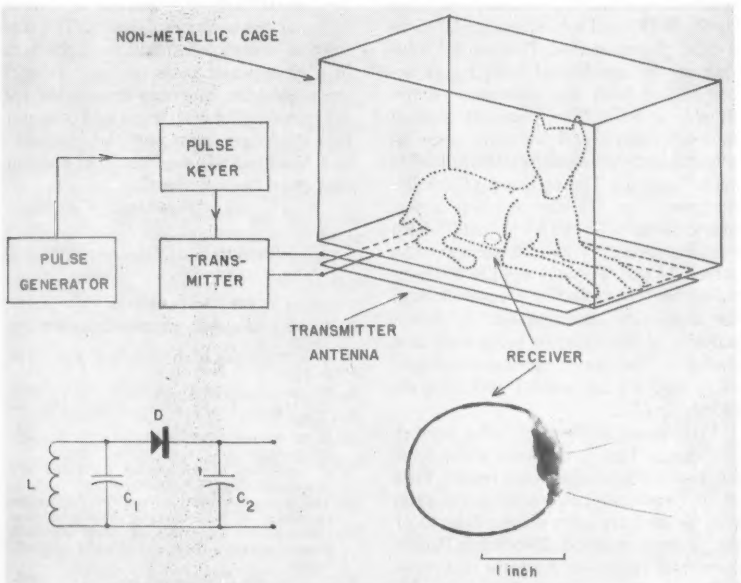

Fig. 1. (Top) Experimental arrangement for remote stimulation of the heart. Radio-frequency carrier 2.5 Mcy/sec; stimulating pulses, 2.5 to 3.7 v, 2 msec. (Bottom, left) Schematic diagram of receiver. **L**, 9 turns of No. 28 Belden enameled wire, approximately 2 in. in diameter; C_1, 200 μμf; C_2, 0.01 μf; **D**, Zener diode, 3.7 v. (Bottom, right) Receiver and output leads. The components are enclosed in a mass of dental cement, shown at extreme right.

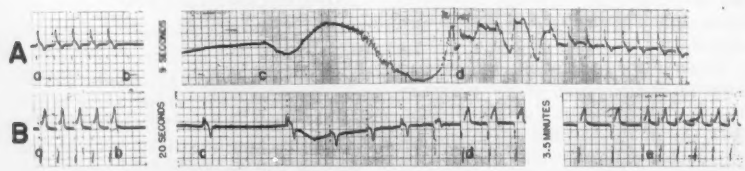

Fig. 2. (*A*) Electrocardiogram of a dog with experimental heart block. At *a*, the ventricles are driven by remote stimulator; at *b*, the stimulator is turned off; at *c*, the dog exhibits convulsion; at *d*, the stimulator is turned on and ventricular contraction resumes. (*B*) Electrocardiogram recorded 3 days later from the same animal. At *a*, the remote stimulator is operating; at *b*, the remote stimulator is turned off; at *c*, the ventricles show spontaneous contractions; at *d*, spontaneous contractions continue, at a higher rate; at *e*, the stimulator is again operating.

Figure 1 (bottom left) shows the schematic diagram of the receiver, which consists of a tank circuit, a Zener diode, and a bypass condenser. When the receiver is completely enclosed within the animal, the components of the tank circuit, instead of being immersed in air, are immersed in a medium of a different dielectric constant. As a consequence, there is a change in the distributed capacitance of the tank circuit and, therefore, in its resonant frequency. For this reason, in order to achieve a satisfactory transmission of the stimulus, the tank circuit has to be tuned to a frequency slightly higher than that of the RF carrier before the receiver is enclosed within the thorax, or the transmitter has to be tuned to a frequency slightly lower than that of the receiver after the latter is enclosed within the thorax. The Zener diode functions as a demodulator and, at the same time, limits the output voltage of the demodulated signal to a desired level, so that changes in the position of the animal which might bring him very close to the transmitting antenna will not result in high stimulating currents causing injury to the myocardium. The stimulating voltage is bound to remain between two limiting values: a maximum value (in these experiments, 3.7 v) determined by the Zener diode and a minimum value (in these experiments, 2.5 v) determined by the fact that the animal cannot remove himself from the transmitting antenna to a distance greater than 1 ft.

Heart block was created in dogs, under Nembutal anesthesia, by opening the right auricle and sectioning the bundle of His in the vicinity of the atrioventricular node. After the creation of the block the receiver was placed between the latissimus dorsi muscle and the rib cage over the 3rd, 4th, and 5th ribs, and its output was connected to the myocardium and to the latissimus dorsi muscle by stainless steel wires insulated with Teflon. During stimulation the lead connected to the heart was negative with respect to the other lead.

Figure 2*A* shows an electrocardiographic record taken 20 hours after the operation from a dog whose ventricular rate had dropped to 40 and who had occasional periods of asystole such that the circulation had to be maintained with the remote stimulator. At *a* the stimulator is functioning and the ventricles are

driven at a rate of approximately 120/min; at *b* the stimulator is turned off and the record shows the absence of ventricular contraction; at *c* the animal exhibits a tonic convulsion; at *d* the stimulator is turned on again, the ventricles are stimulated, and the convulsion ceases.

Figure 2*B* shows an electrocardiographic record taken from the same dog 3 days later. At *a* the ventricles are being stimulated; at *b* the stimulator is turned off and the ventricles stop contracting (only the P wave is visible on the record); at *c* the ventricles begin to contract spontaneously, first slowly, then faster, reaching, at *d*, a rate of approximately 66 per minute; at *e* the stimulator is turned on again.

Animals whose ventricular rate had dropped, after surgical block, below 60 were maintained at normal rates by remote stimulation for periods as long as 8 days (*3*).

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2 June 1958

Method of Polarographic in vivo Continuous Recording of Blood Oxygen Tension

Abstract. A catheter-type PO_2 electrode has been developed which permits the polarographic continuous recording of the blood oxygen tension in vivo. The electrode has been tested in model experiments in vitro and applied in animal experiments lasting several hours. It yielded a continuous tracing of PO_2 with good reproducibility.

The development of a new type of oxygen electrode by Clark (*1*) has given a fresh impetus to the polarographic determination of the oxygen tension in the blood by means of platinum electrodes. In a first step of our studies, we incorporated this electrode into a procedure for measuring the blood oxygen tension in vitro (*2*). This method was thoroughly tested (*3*) by comparing the results with (i) adjusted tonometer equilibrations with determination of the oxygen in the gas phase by the Van Slyke technique and (ii) data obtained from determinations by the Riley technique (*4*). The method is now in routine use for clinical purposes (*5*) and was also used for the calibrations in the new procedure described in this report (*6*).

We have constructed catheter-type PO_2 electrodes for the continuous recording of the blood oxygen tension in vivo by ordinary catheterization. The basic principle is similar to that employed in Clark's electrode (*1*). The catheter consists of Intramedic polyethylene tubing PE 160 (inside diameter, 0.045 in.; outside diameter, 0.062 in.) or PE 200 (inside diameter, 0.055 in.; outside diameter, 0.075 in.) of any desired length. Another thinner polyethylene tubing containing the platinum cathode and its connecting wire was surrounded by the silver anode wire and inserted into the catheter proper; the silver wire at the same time kept the inner tubing concentrically in place. The catheter was filled with saline free of air bubbles and, on the proximal end, was covered with Teflon membrane of thickness 0.001, 0.0005, or 0.00025 in.; the latter was fixed by a specially made very thin ring of stainless steel. The distal end of the catheter was plugged with Seal-All. For the application in animals, the whole catheter-electrode was coated with a thin coat of Velvasil; this procedure effectively prevented any coagulation in the vessel over experimental periods of several hours and did not result in any appreciable loss of sensitivity. The electrodes were freshly assembled and checked in vitro before every animal experiment; this enabled us to service the electrode parts thoroughly every time—that is, to polish the platinum surface and the silver wire.

The current developed by these electrodes was of the order of 1 to 4 μa, depending on the thickness of the Teflon membrane employed (that is, it was similar to or slightly higher than, the current in the case of the Clark electrode) for air at a voltage of 0.6 volts. It was amplified by a General Radio Company type 1230-A d-c amplifier (input resistance 10^4 ohm) and recorded by a Honeywell 906 Visicorder. The amplifier scale permitted immediate readings during the experiment, and the values from the continuous record yielded another set of data for the same conditions.

The performance of these electrodes was always first tested in vitro by taking the calibration curve in various gas mixtures at room temperature several times. Figure 1 shows such a calibration curve (Teflon membrane 0.0005 in. thick). With proper construction of the electrode, we always get straight lines which never go quite through zero but which intersect the ordinate at a rather low reading (the helium reading amounts to about, or less than, 15 percent of the air reading in vitro).

Model experiments were performed in order to explore the effect of various rates of flow and of varying static pressures on the electrode readings. With increasing rates of flow the readings go up slightly and become constant at and above a linear velocity of about 7 cm/sec. The readings remain constant for a range of static pressures between 0 and 120 cm of water. The standard deviation both in vitro and in vivo was never more than 3 percent for any reading, in most cases much less. The response time of these electrodes was about 1.5 sec for 95 percent amplitude and roughly 7 sec for approximately 100 percent amplitude. It depends very much on proper construction of the unit.

A number of dog experiments were carried out in order to test these electrodes in vivo (*7*). The dogs were anesthetized with Nembutal (30 mg/kg). The trachea was intubated or cannulated in order to administer various inspiratory oxygen mixtures. Ventilation was kept constant throughout the experiment, which lasted 2 to 5 hours, by means of an Etsten ventilator (checked by a Bennett ventilation meter) or by a Starling pump; the minute volume of ven-

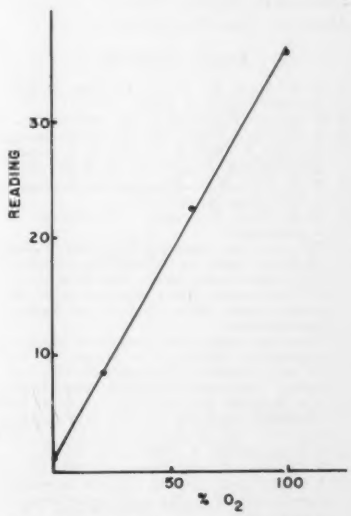

Fig. 1. Calibration curve in vitro with gas.

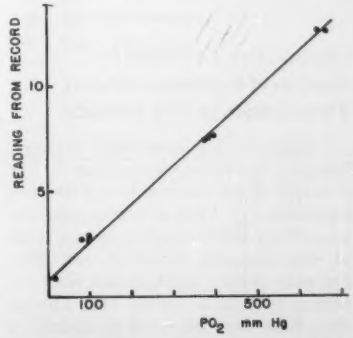

Fig. 2. Calibration curve in vivo in blood.

tilation was in the order of 6 to 10 liter/min, depending on the size of the dog. The catheter electrode was introduced through the carotid artery or femoral artery and was located in the descending aorta. A second sampling catheter was inserted to the same place through which blood samples for the calibration in our in vitro polarograph could be withdrawn.

Figure 2 shows a plot of the readings from the Visicorder tracing against the absolute values of PO_2 in millimeters of mercury as obtained from the samples by the in vitro polarograph—that is, an in vivo calibration curve.

The tracings also show oscillations synchronous with the heart beat, the amplitude of which increase with rising inspiratory oxygen concentrations. Further animal and also model experiments are planned in order to assess the nature of these conditions. In accord with the observations by Sproule *et al.*, we are rather inclined to attribute this phenomenon to a mechanical pulse pressure effect (*8, 9*).

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7. These experiments were carried out partly in collaboration with Dr. T. R. Watson, Jr., and Dr. M. L. Heller of the Cardiopulmonary Laboratory, Hitchcock Foundation, Mary Hitchcock Memorial Hospital, Hanover, N.H. We thank these colleagues for their kind cooperation.
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9. A detailed report on some results of the animal experiments and on the model experiments is in preparation.

8 August 1958

Quantitative Technique for Analysis of Radiation-Induced Tumorization in Fern Prothalli

Tumors occur spontaneously at a very low rate in the in vitro culture of the prothalli of the bracken fern, *Pteridium aquilinum* (*1*). Various nontumorous abnormalities also occur, largely as a result of environmental variations, but these are quite readily distinguished from the tumors by several criteria (*1*). The tumors have been observed to undergo a characteristic nuclear behavior leading from the original haploid prothallial condition to a subsequent polyploidy-aneuploidy by means of endomitotic reduplication and other mitotic abnormalities (*2*). This nuclear change is further characterized by a change in nuclear DNA levels from a stable 1C to 2C range to an extremely variable and heterogeneous distribution of values from the normal to several times that amount (*3*). It was also discovered that the rate of occurrence of the tumors could be greatly increased by applying ionizing radiations to young actively growing prothalli or to dormant spores (*4*). The study of this phenomenon seemed promising if it could be put on a quantitative basis. This is a report on the development of such a technique and a preliminary report of some results obtained (*5*).

The season's supply of field-collected spores (*6*) is cleaned, pooled, and thoroughly mixed. This constitutes the stock from which all experimental materials are drawn during the year. Weighed amounts of spores are taken from the supply. Spores in the experimental lots are x-rayed, while the controls are untreated. Subsequently they are handled in the sterile transfer room, and always in an ascending order with respect to the amount of radiation administered.

The spores are placed into a 15-ml centrifuge tube and wet with 0.5 ml of a 0.1 percent solution of Tween-80. The tube is shaken gently until the spores are no longer clumped. Then 12 ml of a filtered 5 percent solution of Pittchlor (*7*) is added, and the capped tube is shaken vigorously for 2 minutes. The spores are then spun down at moderate speed for about 2½ minutes, and at the end of a total exposure of 5 minutes in the Pittchlor solution the supernatant is quickly poured off, leaving a pellet of spores at the bottom of the tube. These are resuspended in 12 ml of sterile water and spun down again. The water is poured off quickly and the tube is left inverted for a moment to drain the spore pellet completely. The spores are then put into true suspension by adding a measured volume of a medium which matches their density.

Since any appreciable osmotic value of the suspending medium would be objectionable, a large water-soluble molecule that is biologically inert is required. For this purpose the highest available molecular weight of polyethylene glycol (Carbowax 20M) was found satisfactory. Although any momentary density of dormant fern spores newly placed into water is a highly transient state, and is not exactly the same throughout the sample, for the purposes of the present technique a 5 percent solution of Carbowax 20M is a satisfactory approximation of the average spore density during that stage of hydration prevalent at the time of inoculation. A portion of this

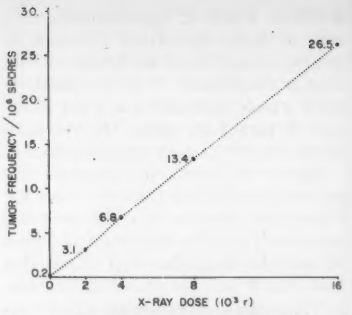

Fig. 1. Dosage-response relationship of ionizing radiations applied to dormant spores of *Pteridium aquilinum*, with the frequency of tumors scored after 6 weeks in culture. The tumor frequency per million spores is plotted against the x-ray dose in thousands of roentgens.

suspension is drawn up into a sterile pipet, and the inoculations are made drop by drop. The surface of the agar medium in the petri plate is pre-wetted by pouring sterile water into the dish and pouring it off before inoculation. This leaves a surface film of water in which the inoculum disperses readily with no clumping, and greatly facilitates subsequent studies of the cultures.

The number of spores in a single drop of the inoculum can readily be determined by the application of blood-counting techniques. The size of the drop and the number of spores that it contains have been found to be very reproducible in any one lot of spores. Approximate uniformity from one lot to another can be obtained by starting with weighed amounts of spores and standardizing procedure throughout.

When the spores have germinated and are of a convenient size—for example, when they are in the two- or three-cell stage, the total numbers of viable spores in single plates are determined. Since we work with large inocula, the counting is most readily done on an enlarged shadowgraph of the entire culture. The 60-mm dish is placed without its cover upon a glass negative carrier in an enlarger, and the image of the culture is projected onto an 8- by 10-in. enlarging paper. This can then be readily counted at a convenient time with the aid of a magnifier.

By using these quantitative techniques, various cultural conditions and other factors such as the safe or tolerable limits of the sterilization process were first investigated and defined more precisely than was earlier possible.

However, the primary objective has been the further analysis of the process of tumorization in the fern gametophyte and especially its increased frequency of occurrence after ionizing radiations. One of the first approaches has been to determine the rate of this occurrence, and to

establish a possible dose-response relationship. Unfiltered 136 kv x-rays were administered to dormant spores at the rate of 1000 r/min for total doses of 2000, 4000, 8000, and 16,000 r, with an unirradiated control. The total numbers of recognizable tumors of all sizes were counted after a 6-week culture period. The frequency of tumors per million spores of the inocula for the various doses is shown in Fig. 1. Approximately 28,000,000 spores were analyzed for the five points shown.

There is as yet no definitive evidence concerning the nature of the basic cellular alteration which occurs in the spores and is eventually expressed as a tumor. It would therefore be premature to attempt to conclude beyond our present data. However, for the sake of a working hypothesis we are inclined to consider this a mutation, or possibly a group of similar mutations. Dormant spores of *Pteridium* are quite radio-resistant, the survival curve extending beyond the limits of the present data by approximately a factor of 10 (*4*). Considering that this is a haploid organism, the type of linearity shown in the dose-response curve (Fig. 1) might be expected of a mutation in this dosage range. Also, at this relatively low frequency of occurrence, an exponential response can be linear (*8*). That dormant spores can be irradiated, kept in continued dormancy for at least another year, and still produce tumors would indicate that the causal event is not transient. It might be said, then, that although there is no evidence which points directly to this being a mutation, neither does any of the evidence at hand contradict this hypothesis. In any case this system and the present approach do present rather unique opportunities for the quantitative analysis of a tumorization process at the cellular level.

The limits of the present experiments were determined by the practical limits of the equipment at hand. Current work is being directed, among other things, toward an extension of these data through the entire viability range to determine both the tumor frequency and the complete survival curve.

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6. I am especially indebted to G. Stinson Lord, Weymouth, Mass., for making all of the spore collections used in these experiments.
7. A commercial product containing 70 percent calcium hypochlorite, manufactured by the Columbia-Southern Chemical Corp., Pittsburgh, Pa.
8. U. Fano, in *Radiation Biology*, A. Hollaender, Ed. (McGraw-Hill, New York, 1954), p. 126.

25 July 1958

An Olfactometer for the Rat

This report describes an apparatus and operant conditioning procedure (*1*) for studying olfactory discrimination in the rat (*2*). A bar-pressing apparatus and dipper mechanism to provide water reinforcement is mounted in a cylindrical glass "wind tunnel." A stream of deodorized air flows continuously through the tunnel at a known velocity. This can be odorized by the addition of known volumes and concentrations of odorized air. The animal is trained to face into the air stream when pressing the bar so that all body odor or odorant adsorbed on the animal's fur is blown out to the rear of the response chamber. The injection of the odorized air is the signal to stop bar-pressing.

The apparatus shown schematically in Fig. 1 shows the response chamber (*b*), containing the bar-press apparatus (*i*) in the cylindrical "wind tunnel" (*j*, *k*), 4 in. in diameter and 12 in. in length. A rotary-vane laboratory pump forces a continuous stream of air through a calcium chloride drying agent and the charcoal and silica gel deodorizing column at a rate of approximately 40 lit. per minute, as monitored by flowmeter *a*. This is the main air stream to the response chamber (*b*).

A small fraction of the air is diverted at *c* through the flowmeter (*d*), via the manifold and stopcocks, to one of four odor bottles (e_1, e_2, e_3, e_4). The odor stream passes over the surface of odorant *f* and returns to the main air stream just in front of the response chamber. Two stationary stainless-steel vanes (*h*) mix the odorized and pure air streams. The

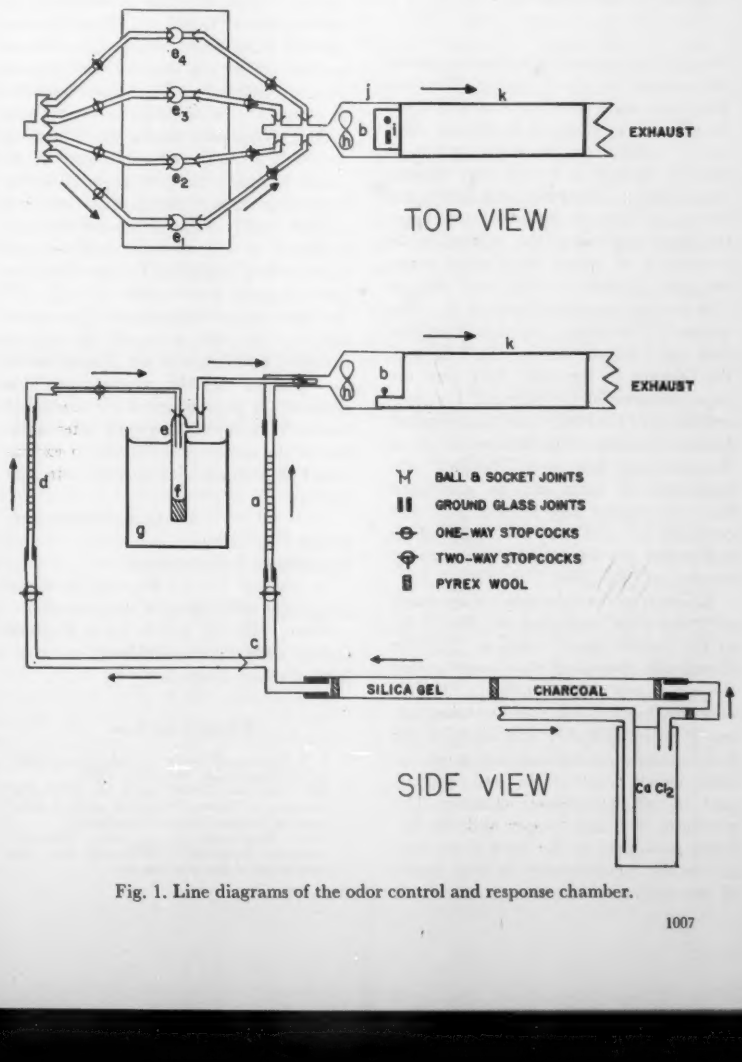

Fig. 1. Line diagrams of the odor control and response chamber.

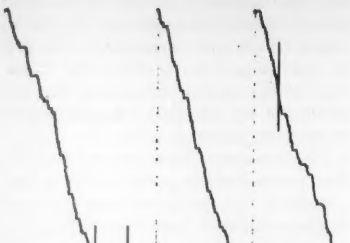

Fig. 2. Sample record of odor discrimination (cumulative response record of bar pressing). The pen moves from the top to the bottom of the record and resets automatically. Note that there is complete cessation of response during the introduction of odor but no diminution of response during the introduction of air from an empty control channel. The pairs of vertical lines on the record were drawn in to show the onset and duration of stimulation indicated by the signal marker.

odor bottles are maintained at a constant temperature by water bath *g*. The outflow from each odor bottle is controlled by a three-way stopcock so that the odor can be added to the main stream or shunted through a bypass (not shown) to an exhaust. This provides a continuous flow of air through the odor bottle when the input stopcock to the odorant bottle is opened, to insure equilibrium when the odor is added to the main stream. The concentration of odorant in the odor stream is a function of the rate of air flow over the odorant surface, the height of the odorant in the odor flask, and the vapor pressure of the odorant. The concentrations of odorant can be computed from the weight of odorant lost for given durations and flow rates. The final concentration of odor can be computed from the relative flow rates of pure and odorized air and may be specified in milligrams per liter, moles per liter, or number of molecules.

All parts of the olfactometer are made of Pyrex glass, including the first 5 in. of the "wind tunnel" section (*j*). The liberal use of ground glass joints makes the entire system easily demountable for cleaning. Section *k* is made of brass tubing 4 in. in diameter and contains the bar-pressing platform and dipper mechanism, which projects 3 in. into the glass part (*b*) of the response chamber. The platform, bar, and dipper and the anterior two-thirds of the animal are visible to the experimenter. A new model of the apparatus has been built (*3*) in which the response chamber is made entirely of glass and in which the bar and drinking font project into the chamber from below, through small ports.

The training procedure is typical of operant discrimination training in which responses are occasionally reinforced in the absence of odor (S^D) but never during the presence of odor (S^Δ). The onset of odor signals the "no-reinforcement" condition. A control training procedure is employed in which clean air from an empty odor bottle is presented, *with reinforcement,* to insure that discrimination is learned on the basis of odor and not of other cues incidental to turning stopcocks, to changes of air pressure, and so on. Odor training (S^Δ) and control training are interspersed randomly. After discrimination has been established, test trials consisting of a 10-second period during which odorized air is introduced and a 10-second odorless control situation are presented, without reinforcement.

In the early experiments we employed a discrimination criterion of fewer than six responses during the 10-second odor test with no diminution in response rate during the 10-second odorless-air control procedure. In order to maintain discrimination at this level, discrimination training trials were continued and interspersed among test trials. Training trials usually consisted of 30 seconds or more of odor (S^Δ) or of odorless control procedure. Responses during the 10-second control test numbered approximately 30 (mode), with a range of from 20 to 40, depending on the animal. A well-trained animal usually stopped bar-pressing immediately in response to a suprathreshold odor, with a negligible latency after the odor stopcock was turned (see Fig. 2). The time before resumption of bar-pressing after the odor is turned off may be variable, but this was not important in the present testing procedure. This method has proved useful for studies of threshold in normal animals after ablation of the olfactory bulbs and in experiments on animals with altered endocrine balance.

CARL PFAFFMANN
Brown University,
Providence, Rhode Island
WILLIAM R. GOFF
University of Virginia, Charlottesville
JOHN K. BARE
College of William and Mary,
Williamsburg, Virginia

References and Notes

1. B. F. Skinner, *Behavior of Organisms* (Appleton-Century-Crofts, New York, 1938).
2. This study was carried out in the psychology laboratory of Brown University, under a grant from the National Science Foundation.
3. Victor Bartosewitz of the Brown University chemistry department constructed the glass components of this olfactometer.

29 July 1958

Chromatography of Molten Salts on a Glass Powder Column

The physicochemical similarity of glasses with zeolithes and with the noncrystalline oxides (silica, alumina) used in chromatography induced us to test the ion-exchange and adsorptive properties of glass under conditions in which these properties might be expected to be of practical use. As a medium, molten salts were selected.

A Pyrex column of inner diameter 8 mm and length 20 cm was filled with Pyrex glass powder (100 to 140 mesh); the column could be slowly charged with the melt. As stopcocks, connecting tubes of length 10 cm and inner diameter 2.5 mm were used. The tubes were placed in sections of the (vertical) oven that could be cooled.

In order to avoid chemical attack on the glass, only salts melting below 400°C were used, such as alkali nitrates and mixtures of alkali halides (preferentially the eutectic mixture of lithium and potassium chlorides, which melts at 352°C).

To this mixture, from 0.1 to 1 percent of chlorides of heavy metals, such as Cr^{III}, Cu^{I}, Ni^{II}, Co^{II}, and Mn^{II}, were added. Separation in zones was observed, which compared in sharpness favorably with those obtained by chromatography in aqueous solution. With the above column and the eutectic mixture used, the adsorption of the heavy metals at 400°C decreased in the above order.

Elution (with pure molten salt) is as easy as in the chromatography from aqueous solutions.

When a small particle of the eutectic mixture of lithium and potassium chlorides, containing one or more heavy metals, is slowly heated to the melting point on a porous Pyrex filter plate, concentric colored circles, showing the differential adsorption of the heavy metals, are observed.

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7 April 1958

Nonpolar Transport of Gibberellin through Pea Stem and a Method for Its Determination

Gibberellin was found to differ from auxin in many physiological effects (*1*). Hence, it is of interest to see whether the transport of gibberellin through the stem is polar or not. As to gibberellin transport, it is only known that gibberellin is transported lengthwise twice as rapidly as transversely (*2*).

A method of determining gibberellins is needed for transport experiments, as

well as for many others. The fluorometry by Phinney *et al.* (*3*) and the method of Bird and Pugh (*4*) are not quantitative. In this report (*5*) a method of using ultraviolet absorption is presented. The basipetal and the acropetal transports of gibberellic acid were compared with each other by means of this method. The dwarf-corn method was also used.

Figure 1 represents the ultraviolet absorption curves of alcohol solutions of gibberellic acid, gibberellin A, and a crude gibberellin preparation (*6*). Gibberellic acid has two peaks of absorption, at 210.5 and 253.5 mμ, while gibberellin A has only one, at 210.0 mμ. The crude gibberellin preparation used also had peaks corresponding to these, with two additional peaks between them.

It was determined by means of ethanol solutions that Beer's law holds for the absorbency at 253.5 mμ of gibberellic acid, at least for concentrations of up to 200 μg/ml, but does not hold for the absorbency of gibberellic acid at 210.5 mμ or for gibberellin A. The absorption curve and the absorbency at 253.5 mμ of gibberellic acid did not change, at least during 24 hours at room temperature. Hence, gibberellic acid may be measured with the absorbency, if proper precautions are taken.

In order to apply to gibberellic acid the method used for the transport of auxin (*7*), the acid contained in agar blocks should be measured. Hence, the most suitable solvent for the extraction from agar was looked for, as follows.

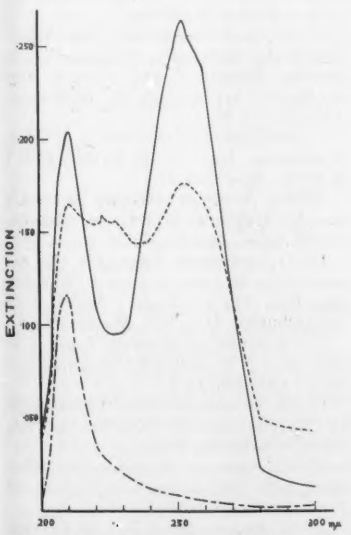

Fig. 1. Ultraviolet absorption curves of ethanol solutions of gibberellic acid (dash-dot line), gibberellin A (broken line), and a crude gibberellin preparation (solid line).

Table 1. Amount of gibberellic acid transported through the pea stem section in the acropetal and in the basipetal directions.

Position of stem section	Gibberellic acid content (μg/block)				Gibberellic acid (μg/stem hr)	
	Donor		Receiver		Disappearing from donor	Transported into receiver
	Initial	Final	Initial	Final		
Normal	11.1	7.0	0	0.87	1.37	0.29
Inverted	11.1	6.4	0	1.02	1.57	0.34

Well-washed agar blocks 35 by 35 by 20 mm³ in size were soaked in 70-percent ethanol for a month, with occasional renewal of ethanol in order to wash out soluble substances from them. They were washed again with distilled water. Thirty-six pea stem sections were put on each agar block, in the normal position or inverted, just as they would be placed in the transport experiment to be conducted. After 3 hours' incubation at 25°C, the blocks were steeped for 24 hours in ethanol, acetone, ether, and acidic ether at 4° to 5°C. A number of blocks were extracted, one by one, separately for each solvent in order to see the probable error. Extracts were evaporated, and ethanol solutions of the residues were assayed spectrophotometrically. Acetone extraction gave the smallest probable error and seemed to be the most suitable. Recovery by acetone from the agar block in which 100 μg of gibberellic acid had been dissolved was about 80 percent. Weak absorbence was detected, even with the extracts made from agar blocks without any treatment.

The extracts from the agar blocks which had been in contact with stem sections, as well as the extracts from the blank blocks, showed no gibberellin reaction in the dwarf-corn test.

Pea seedlings (var. Usui) were grown for 7 days in a darkroom at 25°C. A 5-mm section was excised from the third internode, which was from 15 to 20 mm long. These sections were laid on moistened filter paper for 3 hours in order to let exuding substances out. The sections were then put standing on agar blocks prepared as mentioned above, 36 on each block, in the normal position and inverted. Upon each of the stem sections an agar block 2 by 2 by 2 mm³ in size and containing 11.1 μg of gibberellic acid was placed as the donor. After 3 hours at 25°C the donor blocks and the receiver blocks were extracted with acetone for 24 hours at 4° to 5°C. The extracts were evaporated, the residues were dissolved in ethanol, and the absorbency at 253.5 mμ was measured. The changes in gibberellic acid content of the donor and the receiver blocks are given in Table 1. The acropetal transport was only a little larger than the basipetal.

Bioassay of gibberellic acid in receiver blocks was also made. After 3 and 24 hours of standing, the receiver blocks were extracted as described above. Each dried residue was mixed with 1 g of lanolin. About 60 mg each of the pastes thus prepared was smeared on the seedling of dwarf corn grown in a seeding box under field conditions of from late spring to summer. Gibberellin reaction was positive only with the paste prepared from the blocks which had received gibberellic acid for 24 hours. No difference with respect to the direction of the transporting pea stem sections, however, was observed.

It is thus confirmed that the gibberellic acid transport through pea stem is not notably polar, as auxin transport is known to be (*8*).

JIRO KATO

Department of Botany, Faculty of Science, Kyoto University, Kyoto, Japan

References and Notes

1. B. B. Stowe and T. Yamaki, *Ann. Rev. Plant Physiol.* **8**, 181 (1957).
2. P. M. Neely and B. O. Phinney, *Plant Physiol. Suppl.* 31 (1957).
3. B. O. Phinney, C. A. West, M. Ritzel, P. M. Neely, *Proc. Natl. Acad. Sci. U.S.* **43**, 398 (1957).
4. H. L. Bird, Jr., and C. T. Pugh, *Plant Physiol.* **33**, 45 (1958).
5. This report is No. 4 in a series of studies on the physiological effect of gibberellin.
6. The gibberellic acid used in this study was provided through the courtesy of Dr. C. Leben, of Eli Lilly and Company. The gibberellin A and the crude gibberellin were provided through the courtesy of Prof. Y. Sumiki.
7. F. W. Went and K. V. Thimann, *Phytohormones* (Macmillan, New York, 1937).

8. I wish to thank Prof. Joji Ashida for his cordial guidance in the course of this work and Dr. Bernard O. Phinney, associate professor, University of California, for kindly providing me with dwarf corn seeds.

5 June 1958

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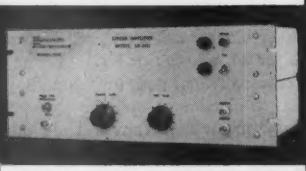

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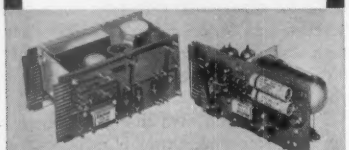

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6

Meetings

Forthcoming Events

November

20–22. Acoustical Soc. of America, 56th meeting, Chicago, Ill. (K. Kramer, 3839 Grand Ave., Western Springs, Ill.)

20–22. American College of Cardiology, New Orleans, La. (P. Reichert, Empire State Bldg., New York 1.)

20–22. International Symp. on Tuberculosis, Philadelphia, Pa. (M. J. Schwartz, Deborah Sanatorium & Hospital, 642 Widener Bldg., Philadelphia 7.)

20–23. American Anthropological Assoc., Washington, D.C. (W. S. Godfrey, Jr., APA Logan Museum, Beloit College, Beloit, Wisc.)

21–22. American Soc. of Animal Production, annual, Chicago, Ill. (H. H. Stonaker, Animal Husbandry Dept., Colorado State Univ., Fort Collins, Col.)

24–26. Fluid Dynamics, division of American Physical Soc., San Diego, Calif. (R. J. Emrich, Dept. of Physics, Lehigh Univ., Bethlehem, Pa.)

24–26. Mechanisation of Thought Processes, symp., Teddington, Middlesex, England. (The Secretary, Natl. Physical Lab., Teddington, Middlesex.)

24–6. Plant Specialists, 4th Latin American conf., Santiago, Chile. (R. Cortazar, Departmento de Investigaciones Agricolas, Ministerio de Agricultura Casilla 4088, Santiago, Chile.)

27–29. Central Assoc. of Science and Mathematics Teachers, 58th annual, Indianapolis, Ind. (N. G. Sprague, Indianapolis Public Schools, 1644 Roosevelt Ave., Indianapolis 18).

28–6. International Conf. of Social Work, 9th intern., Tokyo, Japan. (J. R. Hoffer, Intern. Conf. of Social Work, 345 East 46 St., New York 17, N.Y.)

30–5. American Soc. of Mechanical Engineers, 79th annual, New York, N.Y. (O. B. Schier, ASME, 29 W. 39 St., New York 18.)

December

1–3. American Soc. of Refrigerating Engineers, New Orlenas, La. (R. C. Cross, ASRE, 234 Fifth Ave., New York 1.)

1–4. Entomological Soc. of America, Salt Lake City, Utah. (R. H. Nelson, 1530 P St., NW, Washington, D.C.)

1–5. American Rocket Soc., 13th annual, New York, N.Y. (A. F. Denham, 925 Book Bldg., Detroit 26, Mich.)

2. Scientific Study of Glass, 11th technical meeting of the European Union, Paris, France. (Societe française de ceramique, 44, rue Copernic, Paris 16e.)

2–4. Electric Steel Furnace Conf., 17th, Cleveland, Ohio. (E. O. Kirkendall, AIME, 29 W. 39 St., New York 18.)

2–5. American Medical Assoc., clinical meeting, Minneapolis, Minn. (G. F. Lull, 535 N. Dearborn St., Chicago, Ill.)

3. Animal Care Panel, 9th annual, Chicago, Ill. (R. J. Flynn, Argonne Natl. Laboratory, Lemont, Ill.)

3–5. American Inst. of Electrical Engineers, St. Petersburg, Fla. (N. S. Hibsham, AIEE, 33 W. 39 St., New York 18.)

3–5. Eastern Joint Computers Conf., Philadelphia, Pa. (G. W. Bailey, IRE, 1 E. 79 St., New York 21.)

3–5. Global Communications, 2nd natl. symp., St. Petersburg Beach, Fla. (M. R. Donaldson, 1501 72 St. N., St. Petersburg.)

4–5. Vehicular Communications, annual, Chicago, Ill. (G. W. Bailey, IRE, 1 E. 79 St., New York 21.)

5–7. American Psychoanalytic Assoc., New York, N.Y. (J. N. McVeigh, APA, 36 W. 44 St., New York 36.)

6. American Rheumatism Assoc., Rochester, Minn. (E. F. Hartung, ARA, 580 Park Ave., New York, N.Y.)

6–11. American Acad. of Dermatology and Syphilology, Chicago, Ill. (R. R. Kierland, Mayo Clinic, Rochester, Minn.)

7–10. American Inst. of Chemical Engineers, annual, Cincinnati, Ohio. (F. J. Van Antwerpen, 25 W. 45 St., New York, N.Y.)

8–10. American Nuclear Soc., winter, Detroit, Mich. (ANS, P.O. Box 963, Oak Ridge, Tenn.)

9–10. Conference on Learning Effectiveness, Univ. of Pennsylvania, Philadelphia, Pa. (Air Force Office of Scientific Research, Air Research and Development Command, U.S. Air Force, Washington 25.)

10–16. American Acad. of Optometry, annual, Boston, Mass. (C. C. Koch, 1502 Foshay Tower, Minneapolis, Minn.)

12–13. Association for Research in Nervous and Mental Disease, annual, New York, N.Y. (R. J. Masselink, 700 W. 168 St., New York 32.)

15–17. American Soc. of Agricultural Engineers, winter, Chicago, Ill. (J. L. Butt, American Soc. of Agricultural Engineers, St. Joseph, Mich.)

15–19. Radiation Biology, 2nd Australian conf., Melbourne, Australia. (J. H. Martin, Physics Dept., Cancer Inst. Board, 483 St. Lonsdale St., Melbourne, Victoria.)

17. Institute of Aeronautical Sciences, Washington, D.C. (R. R. Dexter, IAS, 2 E. 64 St., New York 21.)

18–20. American Physical Soc., Los Angeles, Calif. (K. K. Darrow, APS, Columbia Univ., New York 27.)

26–31. American Assoc. for the Advancement of Science, annual, Washington, D.C. (R. L. Taylor, AAAS, 1515 Massachusetts Ave., NW, Washington 5.)

27–29. American Economic Assoc., Chicago, Ill. (J. W. Bell, AEA, Northwestern Univ., Evanston, Ill.)

27–29. Econometric Soc., Chicago, Ill. (R. Ruggles, Box 1264 Yale Station, Yale Univ., New Haven, Conn.)

27–30. American Folklore Soc., New York, N.Y. (MacE. Leach, AFS, Univ. of Pennsylvania, Philadelphia, Pa.)

28–30. Archaeological Inst. of America, Cincinnata, Ohio. (L. A. Campbell, AIA, Dept. of Classics, Brooklyn College, Brooklyn, N.Y.)

29–30. National Council of Teachers of Mathematics, New York, N.Y. (M. H. Ahrendt, NCTM, 1201 16 St., NW, Washington 6.)

28–30. Western Soc. of Naturalists, Seattle, Wash. (J. P. Harville, San Jose State College, San Jose 14.)

(See issue of 17 October for comprehensive list)

Equipment

The information reported here is obtained from manufacturers and from other sources considered to be reliable. Science *does not assume responsibility for the accuracy of the information. A coupon for use in making inquiries concerning the items listed is included in the post card insert.*

■ CABLE EVALUATOR automatically tests for leakage and continuity between any and all wire terminations of a cable harness or device. The unit includes two scanning circuits, a tape reader and code storage unit, a tape punch, an output printer, and leakage- and continuity-detection circuitry. The tape is punched to record continuity found in the test of a reference sample device. Tape produced in this way is used to program the device for comparison tests of other equipment. (James Cunningham Son and Co., Inc., Dept. 409)

■ X-RAY FLUORESCENCE SPECTROMETER permits simultaneous analysis of up to 22 elements in the wavelength range 0.35 to 10.2 A. A ratio-recording system provides inked records showing the concentrations of the elements analyzed. (Applied Research Laboratories, Inc., Dept. 406)

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■ NUCLEAR-COUNTER SIMULATOR for use in developing and testing radiation counting instruments provides recurrent, exponentially shaped voltage pulses simulating the output of a gas-filled nuclear-particle counter tube. Pulse rate is adjustable from 1 to 15 per second and voltage from 0 to 100 mv. (Automation Dynamics Corp., Dept. 414)

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■ LEAK DETECTOR of the helium mass-spectrometer type achieves fivefold increase of sensitivity over previous models by introduction of a butterfly valve between the manifold and the diffusion pump. A leak rate of 2×10^{-10} atmos cm^3/sec of helium will produce 5 percent of full reading. (Consolidated Electrodynamics Corp., Dept. 424)

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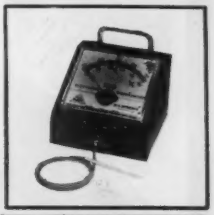

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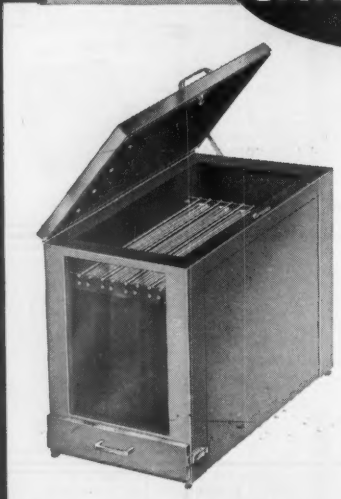

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Where else can you find in one cabinet the corrosion resistance of a Formica lining PLUS the insulation afforded by glass wool PLUS the convenience of a drawer for cleaning and for set-up of ascending chromatograms?

IN ADDITION —

– An especially large triple-pane window lets you see the troughs when introducing solvent through refill holes in the lid.

– The flat top of the cabinet is Formica-covered to give a durable working surface.

PRICE, complete with 4 trough assemblies..... $300.00

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■ TENSILE TESTER consists of separate loading and recording sections for remote testing. Deformation rate is constant and continuously adjustable from 4 to 4000 in./min. The instrument produces a photographic record calibrated in terms of stress, strain, and time. Allegany Instrument Co., Inc., Dept. 416)

■ TESTING MACHINE provides automatic simulation of a wide range of stress and strain at elevated temperatures. Capacity is zero to 50,000 lb. Temperature range extends beyond 3000°F. Ram rates up to ¾ in./sec, temperature rises to 200°F per second, and cycling rates of 10 per second are possible. Variable-reluctance transducers sense strain and load. Measurements are automatically recorded on an 8½- by 11-in. graph. (Marquardt Aircraft Co., Dept. 417)

■ SOLID-STATE BATTERY has a potential of 95v in 0.14 in^3. It can supply 10^{-3} μa for 176,000 hr or a flash current of 20 μa. Voltage per cell is 0.8, and configurations providing 95 v/in. and 625 $v/in.^3$ can be produced. Steady current per square inch of cell area ranges from 10^{-5} amp for 100 hr to 10^{-8} amp for an estimated period of 100,000 hr for a 10-percent voltage drop. Flash current of 200 $\mu a/in.^2$ is obtainable. Temperature coefficient is 1.2×10^{-3} v/deg v between −50° and +50°C. (Universal Winding Co., Dept. 418)

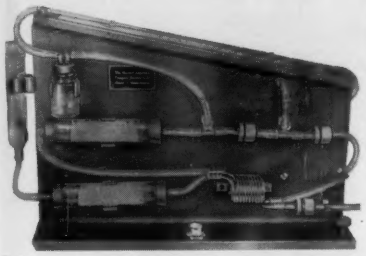
■ FRACTIONATION COMPUTER accepts electrical input signals from instrument transmitters installed in the fractionation process loop and performs computation designed to maintain product quality. Calculations are based on feed flow rate and product analysis. (Southwestern Industrial Electronics Co., Dept. 422)

■ AIRBORNE-PARTICLE SAMPLER is built around a turbine-type blower and has a capacity of 75 ft^3/min. Flow is measured by a self-contained variable-orifice meter. A variety of filters is available. (Nucleonic Corp. of America, Dept. 425)

■ TEMPERATURE RECORDER has sensitivity and accuracy ±0.001°C on a full scale of 0.5°C. The instrument combines a thermistor sensing element and a strip-chart recorder. Any 0.5°C portion of the total range 20° to 30°C may be selected by a switch. Other ranges and multipoint measurement can be furnished. (Fenwal Electronics, Inc., Dept. 426)

■ COOLING COIL is a refrigerated coil that can be immersed in liquid or placed in a cabinet as needed. A rolling cabinet houses the compressor and thermostat. A 5-foot, flexible extension hose couples the tinned-copper cooling coil, measuring 8 in. by 4½ in. in diameter, to the cabinet. Temperature control is main-

CONTINUOUS CO_2 ANALYZER



A simple CO_2 Analyzer based on the critical orifice principle.*

Specifications

Sample flow rate—100 cc./min.

Range—0 to approx. 10% CO_2

Accuracy—$\pm$ 0.05% CO_2

Response time—2 to 3 min. for final reading

Vacuum requirement—simple water aspirator which reduces pressure to at least half atmospheric

Chemicals—Ascarite, Drierite and gauge oil supplied

The analyzer is particularly suited for continuous analysis of both expired gas and alveolar gas (e.g. as provided by Rahn end-tidal sampler) in student physiology laboratories. The sampling rate is such that the unit can be used in series with a Pauling oxygen analyzer.

**J. Mead. A critical orifice CO_2 analyzer suitable for student use. SCIENCE, Vol. 121, Pages 103–4, 1955.*

CO_2 Analyzer, complete—$145.00
F.O.B. Dover, Mass.

HARVARD APPARATUS CO.,
INCORPORATED
Dover, Massachusetts, U.S.A.

(A nonprofit organization)

tained ±2°F from ambient to 5°F. A temperature probe inserted with the cooling coil controls the thermostat. Operation is on 115 v a-c. (Andrew Technical Supply Co., Dept. 429)

■ INDICATOR TUBE of numeral-electrode neon-glow type is available with diameter of 3 in. Digital indication of the tube is said to be readable at distances greater than 150 ft. (Burroughs Corp., Dept. 427)

■ SHAFT-ANGLE DIGITIZER solves the problem of centering of the measuring disk by taking the arithmetic average of two dial readings at diametrically opposite points. Readings are made by two photodiodes counting two waveforms inscribed on the disk. By counting the number of crossings of the two waveforms, digital logic may be applied to follow bidirectional rotation. (Dynamics Research Corp., Dept. 420)

■ FREQUENCY-SELECTIVE VOLTMETER covers the frequency range 1 to 400 kcy/sec. The instrument uses the heterodyne principle and crystal-filter selectivity. A 100-cy/sec-bandwidth filter and a 3-kcy/sec-bandwidth filter are provided. A direct-reading meter is calibrated from −90 to +32 dbm with accuracy ±0.5 db over the instrument range. (Railway Communications, Inc., Dept. 423)

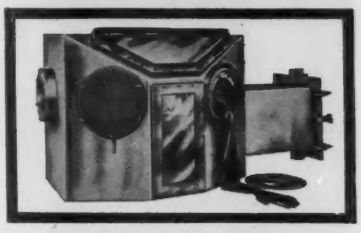
■ SCINTILLATION SPECTROMETER is an automatic instrument that utilizes a step drive to advance the base line sequentially, 1 volt at a time, for up to 100 channels. Counting time for each setting may be from 0.5 to 8 min. Counts are accumulated, and the total is recorded at the end of the chosen period. Count integration for the next channel starts as soon as the previous value has been reset to zero. (Baird-Atomic Inc., Dept. 431)

■ CHLORIDE TITRATOR operates by reacting chloride ions with electrochemically produced silver ions. A constant direct current between a pair of silver electrodes provides silver ions until all chloride has been reacted. At this point unreacted silver ions cause an abrupt increase in conductivity, actuating a relay to interrupt the current and stop a timer. Elapsed time is proportional to chloride content. Titration time usually ranges from 5 to 60 sec. (American Instrument Co., Inc., Dept. 432)

■ POTENTIOSTAT maintains the potential between an electrolyte and a test sample constant by monitoring the potential with a standard electrode. Potential is adjustable between 0 and ±2 v, and current is variable ±50 ma. (Shandon Scientific Co., Ltd., Dept. 449)

JOSHUA STERN
National Bureau of Standards

for work in a controlled atmosphere



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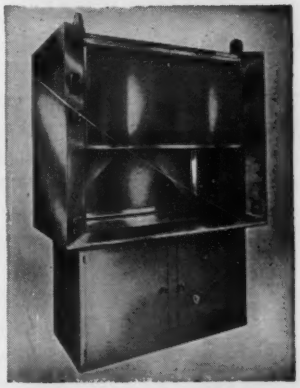
Designed for safe handling of radio-isotopes, reactor fuel containing Plutonium or U233 and other hazardous substances. With air-lock, it can be sealed to create a vacuum. Fabricated of stainless steel plate—34″ long x 26″ high x 24″ wide at base. Air-lock measures 18″ x 12″. Send for Technical Bulletin A-2.

FOR SAFE HANDLING OF RADIOACTIVE MATERIALS



BLICKMAN FUME HOOD

Originally designed and developed for the AEC, this Fume Hood assures maximum safety in the handling of radioactive materials and radioactive isotopes. Sturdy 14-gauge stainless steel, round corner construction provides long life...easy cleaning and decontamination. Send for Technical Bulletin E-3. S. Blickman, Inc., 6910 Gregory Avenue, Weehawken, N. J.

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Look for this symbol of quality Blickman-Built

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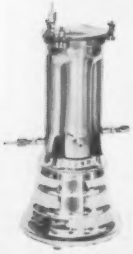
WITHOUT ENDANGERING HUMAN LIFE!

New Safety-Sealed WARING ASEPTIC DISPERSER Eliminates Aerosol Hazard . . . Lab Air Kept Pathogen-Free . . . Design Permits Temperature Control to Insure Maximum Yield

Here is important safety news for everyone concerned with health hazards while liberating microorganisms from diseased tissue. This new stainless steel **Waring Aseptic Disperser** does high speed blending while completely sealed. No infectious aerosol escapes. Fluids are aseptically transferred. Agitator has leakproof bearings. Water jacket provides for temperature regulation.



Any standard Waring Blendor base will operate the **Aseptic Disperser.** Colloidization is so fast and effective, maximum yield is attained. Samples can be removed by hypodermic needle. Entire **Waring Aseptic Disperser** can be autoclaved or otherwise sterilized.

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TITLE_____

COMPANY_____

ADDRESS_____

CITY/ZONE_____ STATE_____

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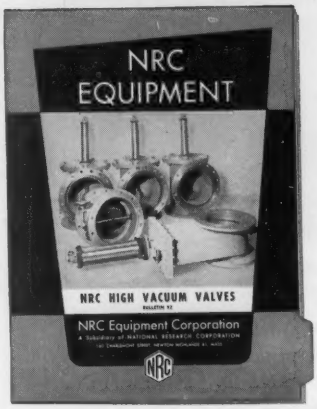

Gives engineering information on types and uses of high vacuum valves. Contains valuable design data on more than 275 valves. Sizes ⅛" to 20" manual and remote operation. Lists wye, globe, angle, slide, ball, air release, throttling and quick connect valves. Write for bulletin No. V3 today!

Department 25-X

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Comfortable to work under too, because you eliminate reflections and disturbing shadows—and provide glare-free illumination.

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POTASSIUM METAPERIODATE (ACS Reagent Grade) For manganese determination; For steel analysis.

PYRIDINIUM BROMIDE PERBROMIDE, $C_5H_5N \cdot HBr \cdot Br_2$, A solid, easily-handled source of Bromine.

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"ZEREWITINOFF" Reagent (1.0 N soln. MeMgI in purified n-butyl ether) For determination of active hydrogen.

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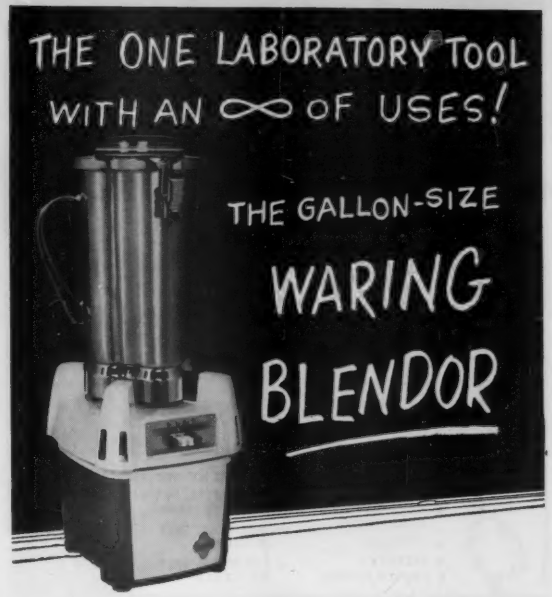

Laboratories have found hundreds of uses for this ruggedly-built, gallon-size Waring Blendor. It does everything from macerating plant material to blending detergent-motor oils . . . everything from mixing pigments to grinding tissue. *Most operations take only a few seconds!* At top speed, the heavy-duty motor whirls stainless steel blades at 14,500 rpm. The stainless steel container is contoured for highest efficiency; has an easy-pour handle and gasketed clamp lid with sampling section.

Save time. Save effort. Save money. Make this versatile Model CB-3 an important part of your standard laboratory equipment. It requires only a 9-inch square space and stands 23 inches high. The 1.5 hp heavy-duty motor is lifetime lubricated—operates on 115 volts, 60 cycles, single phase. Push-button speed selectors for 14,500—12,000—9,000 rpm.

Name your blending problem. Waring engineers will gladly help you solve it.

NOW AVAILABLE SEPARATELY—37½ oz. stainless steel container that withstands rough handling. For standard Waring Blendor.

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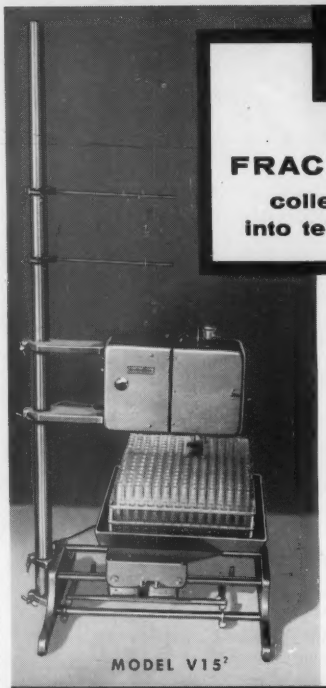
SQUARE FRACTIONATOR

collects directly into test tube racks



MODEL V15²

★ Accurate collection in 225 test tubes

★ 450 tedious test tube transfers are eliminated

★ Equipped with 3 racks — each with 5 rows, 15 tubes per row

★ Improved volumetric unit

★ Timer or N.I.L. drop counter attachment available

The racks themselves, with all the test tubes in the order collected, may be removed from the fractionator for further processing.

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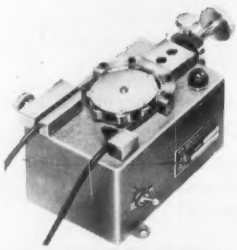
Newly designed scientific research tools...



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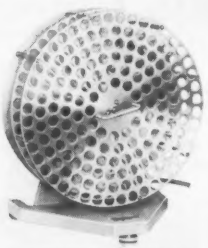
For transferring liquids or gasses through plastic or rubber tubing under controlled conditions.

6 models. Each operates at different speed; each offers flow range through tubing up to ¼" o.d. From 2 ml. *per day* pumped by one model to 75 ml. per minute by another.

Flowing matter never in contact with pump. Tubing is looped into pump, not threaded through an "eye"—perfect for aseptic transfer setups since ends remain contamination-free.

Write for Bulletin PA-S2



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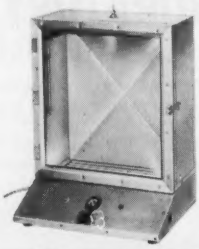
Constant speed or variable speed units with interchangeable trays for various tube sizes, small bottles or eggs.

Speeds as low as 1/5 rpm. available, as well as ranges from 20–120 rpm. Other individual speeds as required.

Write for Bulletin TC-S2



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DIRECTORY OF ADVERTISED PRODUCTS

Classified in the following pages are the products advertised in *Science* in the issues from 25 October 1957 through 17 October 1958. This list is intended to aid laboratory workers in finding the manufacturers of all types of laboratory equipment and supplies. At the end of the classified list is a list of companies that advertised in "The Market Place" section during the period 25 October 1957 through 17 October 1958. An index of advertisers in this issue appears on page 1047.

ABSORPTION CELLS

Klett Manufacturing Co.
1957: 1 Nov., 943; 15 Nov., 1036; 29 Nov., 1129; 13 Dec., 1255; 27 Dec., 1357
1958: 3 Jan., 41; 10 Jan., 100; 17 Jan., 159; 24 Jan., 206; 31 Jan., 251; 7 Feb., 299; 21 Feb., 427; 28 Feb., 446; 7 Mar., 536; 14 Mar., 609; 21 Mar., 657; 28 Mar., 709; 4 Apr., 763; 11 Apr., 827; 18 Apr., 885; 25 Apr., 1000; 2 May, 1071; 9 May, 1129; 16 May, 1193; 23 May, 1260; 30 May, 1295; 6 June, 1354; 13 June, 1403; 27 June, 1514; 4 July, 39; 11 July, 98; 18 July, 155; 25 July, 216; 1 Aug., 259; 8 Aug., 315; 15 Aug., 373; 22 Aug., 431; 29 Aug., 484; 5 Sept., 546; 12 Sept., 611; 19 Sept., 677; 26 Sept., 728; 3 Oct., 783; 10 Oct., 855; 17 Oct., 919

ACCELERATORS, VAN DE GRAAFF

High Voltage Engineering Corp.
1957: 29 Nov., 1094
1958: 3 Jan., 2; 24 Jan., 176; 21 Feb., 382; 21 Mar., 624; 18 Apr., 840; 16 May, 1146; 13 June, 1370; 11 July, 60; 22 Aug., 386; 19 Sept., 630; 17 Oct., 868

ANALYZERS

Applied Physics Corp.
1957: 25 Oct., 873
Eldorado Electronics
1958: 25 July, 208; 8 Aug., 319
Technical Measurement Corp.
1958: 3 Oct., 746

ANIMALS, EXPERIMENTAL

Holtzman Company
1957: 25 Oct., 893; 22 Nov., 1085; 20 Dec., 1309
1958: 17 Jan., 166; 14 Feb., 357; 14 Mar., 614
Taconic Farms
1957: 25 Oct., 893; 15 Nov., 1037; 6 Dec., 1213

ANTIBIOTIC SENSITIVITY INDICATORS

Difco Laboratories
1957: 25 Oct., 857; 22 Nov., 1077; 20 Dec., 1303
1958: 17 Jan., 159; 14 Feb., 355; 14 Mar., 609; 2 May, 1071; 30 May, 1300; 27 June, 1507; 25 July, 215; 22 Aug., 431; 19 Sept., 675; 17 Oct., 919

"ATOMOTRON"

Garfield, Oliver, Co., Inc.
1958: 28 Feb., 481

AUTOCLAVES

Parr Instrument Co.
1957: 25 Oct., 871
Wilmot Castle Co.
1957: 6 Dec., 1203

BAGS, AUTOPSY ROOM

Busse Hospital Products
1958: 14 Mar., 607

BALANCES, ANALYTICAL

Ace Glass, Inc.
1957: 25 Oct., 850
Ainsworth, Wm., & Sons, Inc.
1957: 25 Oct., 860; 15 Nov., 1032; 6 Dec., 1188
1958: 28 Feb., 482, 483; 9 May, 1130, 1131; 18 July, 153; 19 Sept., 669
American Hospital Supply Corp., Scientific Products Div.
1957: 25 Oct., 776
Brinkmann Instruments, Inc.
1957: 1 Nov., 937
1958: 7 Feb., 304; 20 June, 1455; 12 Sept., 605
Central Scientific Co.
1957: 25 Oct., 770
Decker Corp.
1958: 21 Feb., 365
Exact Weight Scale Co.
1958: 28 Mar., 715; 18 Apr., 883; 2 May, 1072; 6 June 1344; 8 Aug., 317
Mettler Instrument Corp.
1957: 25 Oct., 800
1958: 14 Mar., 558; 18 July, 106; 12 Sept., 565
Scientific Glass Apparatus Co., Inc.
1958: 31 Jan., 252; 28 Mar., 708
Standard Scientific Supply Corp.
1958: 25 Apr., 1010
Thomas, Arthur H., Co.
1958: 10 Oct., 860
Torsion Balance Co.
1958: 12 Sept., 558
Welch, W. M., Manufacturing Co.
1958: 7 Mar., 532; 5 Sept., 540

BALANCES, ANIMAL

Exact Weight Scale Co.
1958: 6 June, 1344; 8 Aug., 317
Ohaus Scale Corp.
1958: 30 May, 1297; 26 Sept., 732

BAROMETERS

Central Scientific Co.
1958: 11 July, 97; 12 Sept., 611

BATHS

American Hospital Supply Corp., Scientific Products Div.
1958: 15 Aug., 329
Labline, Inc.
1958: 26 Sept., 726
Sargent, E. H., Co.
1958: 16 May, 1142
Scientific Glass Apparatus Co., Inc.
1958: 25 Apr., 996
Standard Scientific Supply Corp.
1958: 5 Sept., 550

BLOCK AND TACKLE

Scott-Mitchell House, Inc.
1958: 26 Sept., 730

BLOOD GAS APPARATUS

Phipps & Bird, Inc.
1958: 11 July, 97; 25 July, 215
Thomas, Arthur H., Co.
1957: 1 Nov., 944

BOOKS AND JOURNALS

Academic Press, Inc.
1957: 6 Dec., 1204; 20 Dec., 1305
1958: 7 Feb., 301; 21 Feb., 419; 25 Apr., 983
Addison-Wesley Publishing Co., Inc.
1958: 19 Sept., 626
Annual Reviews, Inc.
1957: 25 Oct., 869; 15 Nov., 1033; 6 Dec., 1207
1958: 3 Jan., 44; 21 Feb., 415; 21 Mar., 657; 25 Apr., 997; 16 May, 1199; 6 June, 1351; 4 July, 43; 1 Aug., 261; 5 Sept., 551; 3 Oct., 792
Archaeology
1958: 25 Apr., 988
Basic Books
1958: 25 Apr., 1003; 26 Sept., 687, 727
Biological Laboratory
1958: 2 May, 1067
Cambridge University Press
1958: 25 Apr., 985
Chronicle of United Nations Activities
1958: 27 June, 1511
Consultants Bureau, Inc.
1957: 25 Oct., 852; 8 Nov., 984; 22 Nov., 1078; 13 Dec., 1256; 20 Dec., 1302
1958: 3 Jan., 40; 24 Jan., 198; 31 Jan., 248; 14 Feb., 352; 21 Feb., 426; 7 Mar., 533; 28 Mar., 667; 11 Apr., 820; 18 Apr., 882; 25 Apr., 986; 9 May, 1122; 23 May, 1250; 30 May, 1296; 6 June, 1346; 13 June, 1400; 22 Aug., 426; 5 Sept., 548; 19 Sept., 670; 10 Oct., 846
Cranbrook Institute of Science
1958: 25 Apr., 1000
Doubleday & Co., Inc.
1957: 22 Nov., 1081
1958: 14 Feb., 358; 27 June, 1514
Dover Publications, Inc.
1958: 18 Apr., 837
Dutton, E. P., and Co.
1958: 25 Apr., 999
Garfield, Eugene, Associates
1958: 25 Apr., 927
Harper & Brothers
1958: 23 May, 1254
Harvard University Press
1957: 6 Dec., 1206

1958: 21 Feb., 416; 5 Sept., 542; 17 Oct., 909
Houghton Mifflin Co.
1958: 25 Apr., 992
Humanist Advance Committee
1957: 25 Oct., 886; 13 Dec., 1259
Interscience Publishers, Inc.
1957: 25 Oct., 778
1958: 25 Apr., 921
Lea & Febiger
1957: 6 Dec., 1203
1958: 25 Apr., 925
Library of Science
1958: 21 Feb., 364; 22 Aug., 383; 17 Oct., 911
Little, Brown & Co.
1957: 25 Oct., 879; 29 Nov., 1127; 6 Dec., 1189
Macmillan Co.
1958: 25 Apr., 919
Macy, Josiah, Jr. Foundation
1957: 20 Dec., 1307
1958: 25 Apr., 987; 5 Sept., 545
Maxwell, I. R., & Co., Ltd.
1957: 25 Oct., 802; 29 Nov., 1092; 20 Dec., 1266
1958: 11 Apr., 784; 18 Apr., 838; 11 July, 52
McGraw-Hill Book Co., Inc.
1958: 25 Apr., 915
Mosby, C. V., Co.
1958: 25 Apr., 929
Muirhead Instruments, Inc.
1957: 25 Oct., 867
Ohio State University Press
1958: 28 Feb., 481

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multiplies penetration, resolution, magnification

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Oxford University Press
1958: 21 Feb., 434; 25 Apr., 1006; 12 Sept., 613
Pergamon Press
1957: 1 Nov., 900; 8 Nov., 954; 15 Nov., 996; 22 Nov., 1050; 6 Dec., 1156; 13 Dec., 1220; 27 Dec., 1316
1958: 3 Jan., 6; 10 Jan., 56; 17 Jan., 112; 24 Jan., 174; 31 Jan., 212; 7 Feb., 260; 14 Feb., 312; 21 Feb., 380; 28 Feb., 448; 7 Mar., 498; 14 Mar., 560; 21 Mar., 622; 28 Mar., 672; 4 Apr., 726; 2 May, 1020; 16 May, 1140; 30 May, 1303; 6 June, 1311; 13 June, 1364; 20 June, 1414; 27 June, 1519; 4 July, 4; 26 Sept., 688
Philosophical Library
1957: 25 Oct., 858; 1 Nov., 936; 22 Nov., 1042, 1043
1958: 21 Feb., 423; 28 Feb., 445; 25 Apr., 911
Prentice-Hall, Inc.
1957: 13 Dec., 1255
1958: 14 Feb., 355; 14 Mar., 609; 25 Apr., 991; 10 Oct., 855
Princeton University, Industrial Relations Section
1958: 21 Feb., 428
Reinhold Publishing Corp.
1958: 10 Jan., 54; 25 Apr., 994
Ronald Press Co.
1957: 1 Nov., 939; 6 Dec., 1198
1958: 14 Feb., 351; 25 Apr., 1003; 6 June, 1350; 18 July, 154
Saunders, W. B., Co.
1957: 8 Nov., 947; 6 Dec., 1139
1958: 3 Jan., 3; 14 Feb., 307; 14 Mar., 555; 4 Apr., 725; 11 Apr., 779; 18 Apr., 881; 25 Apr., 899; 2 May, 1065; 9 May, 1083; 16 May, 1143; 23 May, 1203; 6 June, 1307; 4 July, 3; 1 Aug., 223; 12 Sept., 559; 10 Oct., 799
Simmons-Boardman Books
1958: 23 May, 1252
Simon and Schuster, Inc.
1958: 17 Oct., 914
Society for General Systems Research
1958: 25 Apr., 991
Stanford University Press
1957: 6 Dec., 1190
1958: 25 Apr., 988
Thomas, Charles C.
1958: 14 Feb., 348
United Nations
1958: 15 Aug., 328
University of Chicago Press
1957: 13 Dec., 1223
1958: 25 Apr., 923; 23 May, 1206
University of Wisconsin Press
1957: 6 Dec., 1200
Van Nostrand, D., Co., Inc.
1958: 3 Jan., 39; 25 Apr., 931; 12 Sept., 563; 17 Oct., 863
Wiley, John, & Sons, Inc.
1957: 15 Nov., 995; 6 Dec., 1142, 1143
1958: 10 Jan., 51; 14 Feb., 308; 14 Mar., 556; 25 Apr., 902, 903; 10 Oct., 800
Yale University Press
1958: 23 May, 1254
Year Book Publishers, Inc.
1958: 31 Jan., 210

CAGES, ANIMAL

American-Lincoln Incubator Co.
1958: 17 Oct., 918
Porter-Mathews Co., Inc.
1958: 26 Sept., 731

Just published: Vol. 12 (581 pages)

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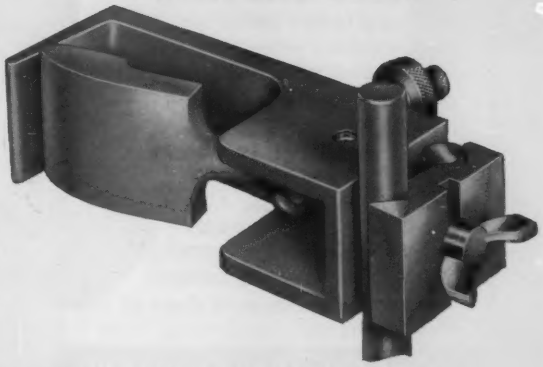

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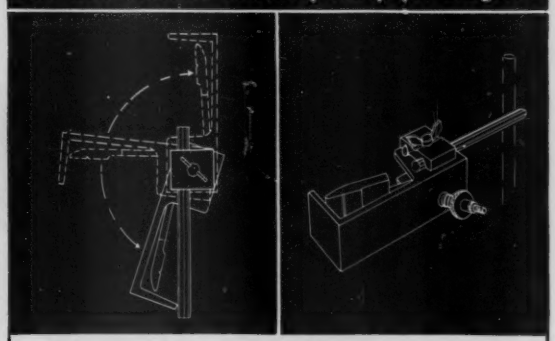

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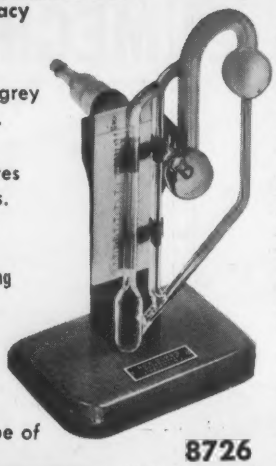

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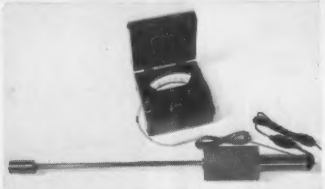

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American Optical Co., Instrument Div.
1958: 3 Oct., 796
Brinkmann Instruments, Inc.
1958: 13 June, 1397
Central Scientific Co.
1957: 15 Nov., 1039; 13 Dec., 1218
1958: 10 Jan., 103; 21 Feb., 368; 28 Mar., 719; 4 Apr., 723
Edmund Scientific Co.
1958: 11 July, 103
Phipps & Bird, Inc.
1958: 21 Feb., 430
Polaroid Corp.
1957: 25 Oct., 773
United Scientific Co., Unitron Instrument Div.
1958: 26 Sept., 739

CATALOGS

Allied Radio
1958: 3 Jan., 43; 21 Feb., 419
American-Lincoln Incubator Co.
1958: 17 Oct., 918
American Optical Co., Instrument Div.
1957: 22 Nov., 1088
1958: 18 Apr., 896
Applied Physics Corp.
1957: 6 Dec., 1193
Atomic Accessories, Inc.
1957: 25 Oct., 890
Baird-Atomic, Inc.
1957: 6 Dec., 1194
Bausch & Lomb Optical Co.
1957: 8 Nov., 956; 6 Dec., 1158; 20 Dec., 1270; 27 Dec., 1354
1958: 17 Jan., 114; 31 Jan., 214; 28 Mar., 674; 9 May, 1090; 20 June, 1418; 1 Aug., 226; 15 Aug., 336; 29 Aug., 444; 26 Sept., 692
Beckman Instruments, Inc., Scientific and Process Instruments Div.
1958: 12 Sept., 614
Bellco Glass, Inc.
1957: 25 Oct., 891; 27 Dec., 1357
1958: 14 Mar., 611; 11 Apr., 822; 25 Apr., 1005; 30 May, 1295
California Corporation for Biochemical Research
1958: 18 July 108; 29 Aug., 491
Clay-Adams, Inc.
1957: 6 Dec., 1207
Colorado Serum Co.
1957: 25 Oct., 869; 15 Nov., 1026
1958: 21 Feb., 415; 25 Apr., 999; 16 May, 1196; 13 June, 1397
Corning Glass Works
1957: 6 Dec., 1153
1958: 3 Jan., 5; 14 Feb., 351; 7 Mar., 491; 11 Apr., 818; 2 May, 1079; 5 Sept., 499
Duralab Equipment Corp.
1958: 3 Oct., 791
Edmund Scientific Co.
1958: 6 June, 1310
Fisher Scientific Co.
1958: 8 Aug., 314; 10 Oct., 852
Greiner, Emil, Co.
1958: 12 Sept., 561
Harshaw Chemical Co.
1957: 25 Oct., 877
Lourdes Instrument Corp.
1958: 26 Sept., 725
Metalab Equipment Co.
1957: 25 Oct., 866
Nalge Co., Inc.
1957: 27 Dec., 1356

1958: 17 Jan., 162; 21 Feb., 420; 25 Apr., 914; 16 May, 1188; 13 June, 1396; 18 July, 158; 8 Aug., 318; 19 Sept., 668

National Research Corp., NRC Equipment Corp.
1958: 5 Sept., 542

Nutritional Biochemicals Corp.
1957: 25 Oct., 853; 8 Nov., 952; 22 Nov., 1081; 6 Dec., 1189; 20 Dec., 1304
1958: 3 Jan., 41; 17 Jan., 110; 31 Jan., 251; 14 Feb., 358; 28 Feb., 446; 14 Mar., 611; 28 Mar., 709; 11 Apr., 827; 25 Apr., 991; 9 May, 1132; 23 May, 1253; 6 June, 1351; 20 June, 1455; 4 July, 39; 18 July, 159; 1 Aug., 264; 15 Aug., 375; 29 Aug., 487; 12 Sept., 616; 26 Sept., 724; 10 Oct. 851

Olympus Optical Instrument Co.
1957: 6 Dec., 1197

Research Specialties Co.
1958: 21 Feb., 430

Sanborn Co.
1957: 6 Dec., 1149; 20 Dec., 1269
1958: 17 Jan., 111

Schwarz Laboratories, Inc.
1958: 16 May, 1186

Sigma Chemical Co.
1958: 10 Jan., 99; 14 Feb., 355; 14 Mar., 615; 25 Apr., 997; 23 May, 1259; 20 June, 1449; 18 July, 155; 15 Aug., 373; 10 Oct., 854

Tracerlab, Inc.
1958: 21 Mar., 655

United Scientific Co., Unitron Instrument Div.
1957: 25 Oct., 781; 8 Nov., 986; 22 Nov., 1082; 13 Dec., 1222
1958: 7 Feb., 297; 14 Feb., 350; 21 Feb., 371; 28 Feb., 481; 7 Mar., 493; 14 Mar., 606; 21 Mar., 652; 28 Mar., 712; 4 Apr., 764; 11 Apr., 819; 18 Apr., 835; 25 Apr., 999; 2 May, 1070; 9 May, 1125; 23 May, 1254; 30 May, 1298; 13 June, 1403; 27 June, 1469; 25 July, 171; 5 Sept., 547; 12 Sept., 612; 19 Sept., 668; 3 Oct., 791

Will Corp.
1957: 15 Nov., 1031
1958: 24 Jan., 200; 21 Mar., 654; 25 Apr., 984; 16 May, 1191; 18 July, 157; 22 Aug., 432

Wilmot Castle Co.
1957: 25 Oct., 854

Winthrop Laboratories
1958: 14 Feb., 348; 21 Mar., 657; 25 Apr., 1000

CENTRIFUGES

Beckman Instruments, Inc., Spinco Div.
1957: 25 Oct., 785; 6 Dec., 1147
1958: 28 Feb., 487; 25 Apr., 926; 19 Sept., 622; 17 Oct., 862

International Equipment Co.
1957: 25 Oct., 783; 8 Nov., 949; 22 Nov., 1087; 6 Dec., 1141
1958: 21 Feb., 439; 21 Mar., 621; 25 Apr., 913; 23 May, 1263; 20 June, 1416; 18 July, 111; 19 Sept., 627; 17 Oct., 866

Labline, Inc., Chicago Surgical & Electrical Co. Div.
1958: 2 May, 1069; 29 Aug., 438

Little, Arthur D., Inc., Engineering Div.
1957: 25 Oct., 784

Lourdes Instrument Corp.
1957: 25 Oct., 775
1958: 24 Jan., 171; 7 Mar., 534; 25 Apr., 924; 26 Sept., 725

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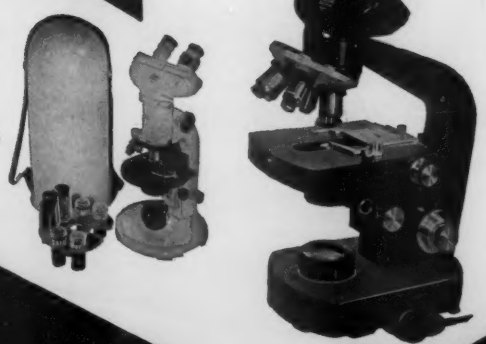

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Sorvall, Ivan, Inc.
1957: 25 Oct., 791; 6 Dec., 1155
1958: 24 Jan., 207; 21 Feb., 370; 28 Mar., 670; 25 Apr., 918; 23 May, 1208; 20 June, 1415; 18 July, facing 136; 22 Aug., 384; 26 Sept., 690
Standard Scientific Supply Corp.
1957: 25 Oct., 876

CENTRIFUGE ACCESSORIES

American Hospital Supply Corp., Scientific Products Div.
1958: 15 Aug., 329
Beckman Instruments, Inc., Spinco Div.
1957: 25 Oct., 785; 6 Dec., 1147
1958: 17 Oct., 862
Corning Glass Works
1958: 2 May, 1079
International Equipment Co.
1958: 20 June, 1416; 18 July, 111
Lourdes Instrument Corp.
1957: 25 Oct., 775
1958: 7 Mar., 534; 25 Apr., 924
Nalge Co., Inc.
1958: 25 Apr., 914; 18 July, 158
Standard Scientific Supply Corp.
1957: 25 Oct., 876

CHARTS, BIOLOGICAL

Welch, W. M., Manufacturing Co.
1957: 6 Dec., 1189

CHEMICALS, BIOLOGICAL

Arapahoe Chemicals, Inc.
1957: 25 Oct., 861
Borden Co., Chemical Div.
1958: 24 Jan., 204; 21 Feb., 430; 7 Mar., 532; 25 Apr., 993; 23 May, 1260; 17 Oct., 919
California Corporation for Biochemical Research
1958: 18 July, 108; 29 Aug., 491
Clinton Laboratories
1957: 25 Oct., 889
1958: 11 July, 98
Difco Laboratories
1957: 25 Oct., 857; 22 Nov., 1077; 20 Dec., 1303
1958: 17 Jan., 159; 14 Feb., 355; 14 Mar., 609; 2 May, 1071; 30 May, 1300; 25 July, 215; 22 Aug., 431; 19 Sept., 675; 17 Oct., 919
Isotopes Specialties Co., Inc.
1958: 17 Jan., 165; 7 Mar., 532
Mann Research Laboratories, Inc.
1958: 28 Feb., 481; 28 Mar., 713; 25 Apr., 987; 23 May, 1259; 26 Sept., 731
Nutritional Biochemicals Corp.
1957: 25 Oct., 853; 8 Nov., 952; 22 Nov., 1081; 6 Dec., 1189; 20 Dec., 1304
1958: 3 Jan., 41; 17 Jan., 110; 31 Jan., 251; 14 Feb., 358; 28 Feb., 446; 14 Mar., 611; 28 Mar., 709; 11 Apr., 827; 25 Apr., 991; 9 May, 1132; 23 May, 1253; 6 June, 1351; 20 June, 1455; 4 July, 39; 18 July, 159; 1 Aug., 264; 15 Aug., 375; 29 Aug., 487; 12 Sept., 616; 26 Sept., 724; 10 Oct., 851
Pabst Brewing Co., Pabst Laboratories Div.
1957: 1 Nov., 902
Schwarz Laboratories, Inc.
1957: 25 Oct., 851; 15 Nov., 1027; 6 Dec., 1191; 27 Dec., 1355
1958: 24 Jan., 201; 21 Feb., 417; 7 Mar., 547; 16 May, 1186; 20 June, 1457; 18 July, 160; 29 Aug., 485; 5 Sept., 543; 17 Oct., 913
Sigma Chemical Co.
1957: 6 Dec., 1195
1958: 10 Jan., 99; 14 Feb., 355; 14 Mar., 615; 25 Apr., 997; 9 May, 1124; 23 May, 1259; 20 June, 1449; 18 July, 155; 15 Aug., 373; 12 Sept., 609; 10 Oct., 854, 855
Winthrop Laboratories
1957: 25 Oct., 875; 29 Nov., 1129
1958: 14 Feb., 348; 21 Mar., 657; 25 Apr., 1000; 30 May, 1295; 11 July, 94
Worthington Biochemical Co.
1957: 25 Oct., 794

CHEMICALS, GENERAL

Borden Co., Chemical Div.
1958: 24 Jan., 204; 25 Apr., 993
Foote Mineral Co.
1958: 28 Feb., 444; 28 Mar., 671; 23 May, 1205; 11 July, 53; 19 Sept., 625
Harshaw Chemical Co.
1957: 25 Oct., 877; 15 Nov., 1033; 6 Dec., 1211
1958: 10 Jan., 97; 21 Feb., 421; 16 May, 1189; 15 Aug., 367; 19 Sept., 671
Isomet Corp.
1958: 21 Feb., 419; 7 Mar., 548
LaMotte Chemical Products Co.
1957: 25 Oct., 872
Lithium Corporation of America, Inc.
1957: 25 Oct., 788
Mallinckrodt Chemical Works
1958: 25 Apr., 905; 8 Aug., 271; 3 Oct., 743
Schwarz Laboratories, Inc.
1958: 16 May, 1186
Scientific Glass Apparatus Co., Inc.
1957: 25 Oct., 880
Sigma Chemical Co.
1958: 9 May, 1124
Thomas, Arthur H., Co.
1958: 1 Aug., 268
Weizmann Institute of Science, Isotope Dept.
1958: 25 Apr., 999; 16 May, 1190; 13 June, 1398; 11 July, 100; 15 Aug., 368; 12 Sept., 606

CHEMICALS, ORGANIC

Arapahoe Chemicals, Inc.
1958: 25 Apr., 1009
Harshaw Chemical Co.
1958: 21 Mar., 651; 18 Apr., 885; 16 May, 1189; 15 Aug., 367

CHEMICALS, TRACER

Radiochemical Centre
1958: 18 July, 167; 15 Aug., 375; 12 Sept., 605
Research Specialties Co.
1957: 29 Nov., 1132; 6 Dec., 1205
1958: 17 Jan., 110; 16 May, 1199; 5 Sept., 541
Schwarz Laboratories, Inc.
1957: 15 Nov., 1027; 6 Dec., 1191
1958: 24 Jan., 201; 11 Apr., 821; 16 May, 1186; 20 June, 1457; 18 July, 160; 17 Oct., 913

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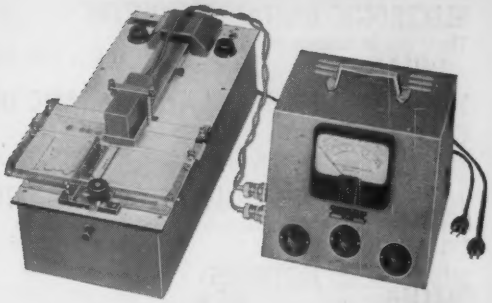

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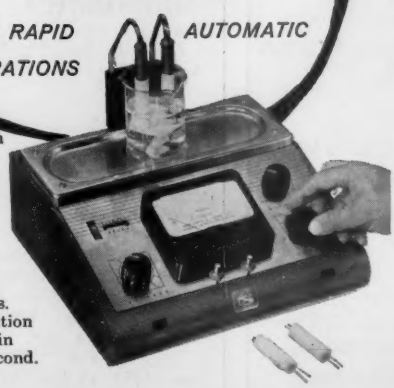

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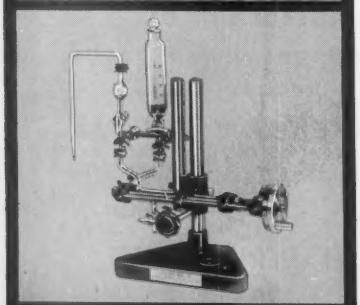

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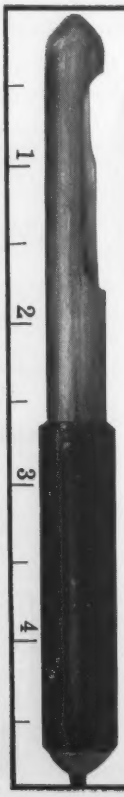

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pencil type lamp
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8 models, ideal for far U.V. examination of small areas.

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Also, complete line of near and far ultra-violet lamps 4-100 watts available in various sizes and models.

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ULTRA-VIOLET PRODUCTS Inc.
San Gabriel, California

CHROMATOGRAPHY EQUIPMENT

Angel, H. Reeve, & Co., Inc.
1957: 6 Dec., 1148
Beckman Instruments, Inc., Scientific Instrument Div.
1958: 13 June, 1367; 8 Aug., 270; 26 Sept., 686
California Laboratory Equipment Co.
1958: 11 Apr., 823; 9 May, 1123; 1 Aug., 264
Central Scientific Co.
1958: 7 Mar., 490; 25 July, 215; 5 Sept., 546
Eaton-Dikeman Co.
1958: 16 May, 1194
Labline, Inc.
1957: 25 Oct., 881; 29 Nov., 1127
New York Laboratory Supply Co., Inc.
1958: 21 Feb., 424
Nuclear-Chicago Corp.
1958: 4 Apr., 724; 23 May, 1264
Nuclear Corporation of America, NRD Instrument Co. Div.
1958: 27 June, 1515
Packard Instrument Co.
1958: 10 Jan., 98; 7 Mar., 538; 11 July, 99; 5 Sept., 552; 3 Oct., 790
Photovolt Corp.
1957: 22 Nov., 1081; 13 Dec., 1255
1958: 3 Jan., 41; 7 Feb., 299; 14 Mar., 615; 9 May, 1132; 27 June, 1507; 25 July, 211; 15 Aug., 367; 5 Sept., 545; 19 Sept., 671
Research Specialties Co., Reco Div.
1957: 22 Nov., 1077
1958: 14 Mar., 610; 18 Apr., 888; 4 July, 38; 1 Aug., 260; 26 Sept., 729
Scientific Glass Apparatus Co.
1957: 22 Nov., 1048
1958: 21 Feb., 372
Thomas, Arthur H., Co.
1958: 6 June, 1360

CLEANING EQUIPMENT

Aloe, A. S., Co., Aloe Scientific Div.
1958: 3 Oct., 785; 17 Oct., 919
Branson Ultrasonic Corp.
1958: 17 Oct., 918
Fisher Scientific Co.
1958: 9 May, 1128
Narda Ultrasonics Corp.
1958: 10 Jan., 99; 14 Mar., 615; 25 Apr., 1005; 16 May, 1189; 9 Sept., 677

CLEANSERS

Alconox, Inc.
1958: 19 Sept., 680
American Hospital Supply Corp., Scientific Products Div.
1958: 21 Feb., 374
Linbro Chemical Co.
1957: 25 Oct., 855; 6 Dec., 1197
1958: 10 Jan., 97; 21 Feb., 427; 14 Mar., 609; 25 Apr., 1009
Meinecke & Co., Inc.
1958: 14 Feb., 353; 11 Apr., 825; 20 June, 1458; 15 Aug., 372; 12 Sept., 613; 10 Oct., 848

COLORIMETERS

Bausch & Lomb Optical Co.
1957: 8 Nov., 956
1958: 9 May, 1090; 1 Aug., 226
New York Laboratory Supply Co., Inc.
1958: 7 Mar., 539

COMBUSTION APPARATUS

Thomas, Arthur H., Co.
1958: 21 Feb., 440

COMPUTING INSTRUMENTS

Philbrick, George A., Researches, Inc.
1958: 9 May, 1088

CONDENSERS

Ace Glass, Inc.
1958: 6 June, 1350

CRUCIBLES

Ace Glass Inc.
1958: 11 Apr., 825

CURRENT INTEGRATOR

Eldorado Electronics
1958: 9 May, 1120; 12 Sept., 612

DENSITOMETERS

Photovolt Corp.
1957: 22 Nov., 1081; 13 Dec., 1255
1958: 3 Jan., 41; 7 Feb., 299; 14 Mar., 615; 9 May, 1132; 27 June, 1507; 25 July, 211; 15 Aug., 367; 5 Sept., 545; 19 Sept., 671

DESALTERS

Research Specialties Co., Reco Div.
1957: 20 Dec., 1303
1958: 24 Jan., 199; 28 Mar., 713
Scientific Glass Apparatus Co.
1957: 22 Nov., 1048

DESICCATORS

Ace Glass, Inc.
1958: 9 May, 1126; 29 Aug., 482
Phipps & Bird, Inc.
1957: 22 Nov., 1079

DIALYZERS

Oxford Laboratories
1957: 25 Oct., 863

DIFFRACTION GRATINGS

Farrand Optical Co., Inc.
1957: 25 Oct., 795
1958: 13 June, 1397; 15 Aug., 373

DIFFRACTOMETERS

Philips Electronics, Inc., Instruments Div.
1957: 6 Dec., 1140

DOSIMETERS

Cambridge Instrument Co., Inc.
1958: 3 Oct., 785

DRILLS

Scott-Mitchell House, Inc.
1958: 26 Sept., 730

ELECTROMETERS

Applied Physics Corp.
1957: 25 Oct., 873; 6 Dec., 1193
1958: 25 Apr., 989; 22 Aug., 427
Atomic Accessories, Inc.
1957: 25 Oct., 890
Cambridge Instrument Co.
1957: 25 Oct., 869

Positive stop readings in 1.13 seconds

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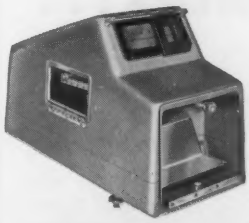

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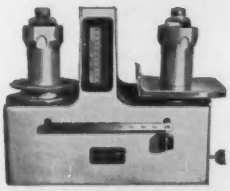

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Model 4206B-TC also for general laboratory use and small-animal weighing. Has tare control knob to zero the dial, or position for over-and-under reading. Capacity 3 kilos; sensitivity to 350 milligrams. Dial is graduated 0-100 grams in increments of 1 gram. Beam 500 grams by 5 grams.

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Nuclear-Chicago Corp.
1958: 21 Mar., 664; 25 Apr., 900; 20 June, 1464

ELECTROPHORESIS APPARATUS

Beckman Instruments, Inc., Spinco Div.
1957: 8 Nov., 946
1958: 28 Mar., 668; 11 Apr., 782; 23 May, 1207; 15 Aug., 380; 29 Aug., 441
Eaton-Dikeman Co.
1958: 16 May, 1194
E-C Apparatus Co.
1957: 25 Oct., 853
Kern Co.
1957: 25 Oct., 857
Klett Manufacturing Co.
1957: 25 Oct., 875; 1 Nov., 943; 8 Nov., 952; 15 Nov., 1036; 22 Nov., 1079; 29 Nov., 1129; 6 Dec., 1197; 13 Dec., 1255; 20 Dec., 1305; 27 Dec., 1357
1958: 3 Jan., 41; 10 Jan., 100; 17 Jan., 159; 24 Jan., 206; 31 Jan., 251; 7 Feb., 299; 21 Feb., 427; 28 Feb., 446; 7 Mar., 536; 14 Mar., 609; 21 Mar., 657; 28 Mar., 709; 4 Apr., 763; 11 Apr., 827; 18 Apr., 885; 25 Apr., 1000; 2 May, 1071; 9 May, 1129; 16 May, 1193; 23 May, 1260; 30 May, 1295; 6 June, 1354; 13 June, 1403; 27 June, 1514; 4 July, 39; 11 July, 98; 18 July, 155; 25 July, 216; 1 Aug., 259; 8 Aug., 315; 15 Aug., 373; 22 Aug., 431; 29 Aug., 484; 5 Sept., 546; 12 Sept., 611; 19 Sept., 677; 26 Sept., 728; 3 Oct., 783; 10 Oct., 855; 17 Oct., 919

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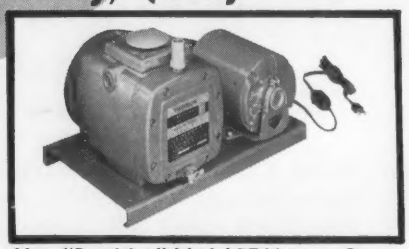

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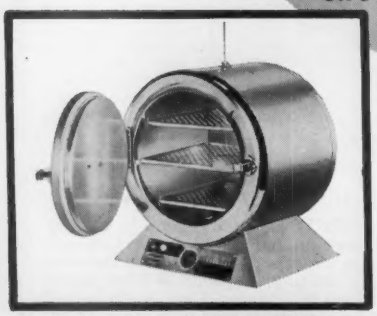

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Variations held within 1° C.

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• chemicals
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SCIENTIFIC GLASS APPARATUS CO., INC.
BLOOMFIELD, NEW JERSEY

Labline, Inc.
1957: 25 Oct., 881; 29 Nov., 1127
Laboratory Glass & Instruments Corp.
1958: 25 Apr., 908
New York Laboratory Supply Co., Inc.
1958: 21 Feb., 424
Perkin-Elmer Corp., Instrument Div.
1957: 25 Oct., 789
Phipps & Bird, Inc.
1957: 8 Nov., 987
1958: 25 Apr., 1005
Photovolt Corp.
1957: 25 Oct., 877; 8 Nov., 985; 22 Nov., 1081; 6 Dec., 1205; 13 Dec., 1255
1958: 3 Jan., 41; 31 Jan., 251; 7 Feb., 299; 21 Feb., 433; 14 Mar., 615; 21 Mar., 657; 18 Apr., 885; 9 May, 1132; 23 May, 1251; 20 June, 1455; 27 June, 1507; 18 July, 167; 25 July, 211; 15 Aug., 367; 22 Aug., 431; 5 Sept., 545; 19 Sept., 671
Scientific Glass Apparatus Co.
1958: 21 Feb., 372

EVAPORATORS

Laboratory Glass & Instruments Corp.
1958: 25 Apr., 908; 25 July, 170
Phipps & Bird, Inc.
1958: 13 June, 1401

FALLING DROP APPARATUS

Polarad Electronics Corp.
1957: 6 Dec., 1208
1958: 6 June, 1349

FILM BADGES

Controls for Radiation, Inc.
1958: 24 Jan., 203; 7 Feb., 297; 7 Mar., 546; 9 May, 1124; 23 May, 1251; 13 June, 1399; 18 July, 164; 10 Oct., 848

FILMS, EDUCATIONAL

Moody Institute of Science
1957: 6 Dec., 1209

FILTERS

Ace Glass, Inc.
1958: 11 Apr., 825
Baird-Atomic, Inc.
1958: 18 Apr., 884
Barnstead Still & Demineralizer Co.
1957: 25 Oct., 872
Dell Optics Co., Ltd.
1958: 18 Apr., 889

FILTERS, INTERFERENCE

Axler Associates, Inc.
1958: 25 Apr., 1002
Bausch & Lomb Optical Co.
1958: 3 Jan., 8
Baird-Atomic, Inc.
1958: 18 Apr., 884
Farrand Optical Co., Inc.
1957: 15 Nov., 1029; 6 Dec., 1208
Fish-Schurman Corp.
1957: 6 Dec., 1192
Photovolt Corp.
1958: 30 May, 1295; 11 July, 97; 29 Aug., 487; 10 Oct., 851

FILTER PAPER

Ace Glass, Inc.
1957: 25 Oct., 850
Angel, H. Reeve, & Co., Inc.
1957: 6 Dec., 1148

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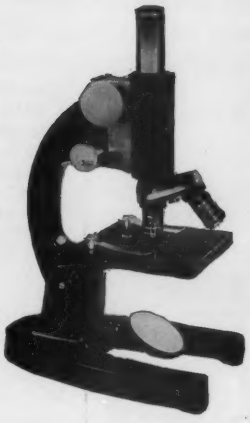

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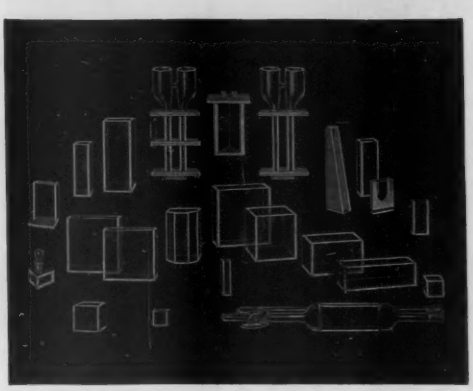

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PLAIN TYPE with non-metallic, dead-air insulating jacket. Can be equipped with either single or double valve, Parr self-sealing oxygen bombs. Excellent for routine tests of coal, petroleum products and foodstuffs, also for student instruction in calorimetry.

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Eaton-Dikeman Co.
1958: 16 May, 1194
Fisher Scientific Co.
1957: 25 Oct., 779
New York Laboratory Supply Co., Inc.
1958: 7 Mar., 539
Thomas, Arthur H., Co.
1958: 6 June, 1360

FLASKS

Ace Glass, Inc.
1958: 1 Aug., 258
Bellco Glass, Inc.
1957: 6 Dec., 1192
1958: 31 Jan., 251
Corning Glass Works
1957: 6 Dec., 1153
Nalge Co., Inc.
1957: 27 Dec., 1356
Palo Laboratory Supplies, Inc.
1958: 25 July, 211

FLUOROMETERS

Biddle, James G., Co.
1957: 25 Oct., 885
Coleman Instruments, Inc.
1957: 25 Oct., 886
1958: 27 June, 1509; 10 Oct., 847
Farrand Optical Co., Inc.
1958: 17 Jan., 159; 21 Feb., 415; 21 Mar., 651; 5 Sept., 544
Photovolt Corp.
1957: 29 Nov., 1129
1958: 10 Jan., 97; 28 Feb., 481; 28 Mar., 713; 11 Apr., 827; 13 June, 1404; 1 Aug., 261; 12 Sept., 609; 7 Oct., 909

FRACTIONATORS

E-C Apparatus Co.
1957: 25 Oct., 889
Gilson Medical Electronics
1958: 5 Sept., 494

FRACTION COLLECTORS

Aloe, A. S., Co., Aloe Scientific Div.
1958: 6 June, 1351
Microchemical Specialties Co.
1958: 6 June, 1347
National Instrument Laboratories, Inc.
1957: 25 Oct., 861
Packard Instrument Co.
1957: 6 Dec., 1201
1958: 10 Jan., 98; 7 Mar., 538; 6 June, 1355; 11 July, 99; 5 Sept., 552; 3 Oct., 790
Research Specialties Co.
1957: 25 Oct., 879; 8 Nov., 987; 13 Dec., 1257
1958: 10 Jan., 96; 31 Jan., 250; 23 May, 1256; 25 July, 210; 19 Sept., 676
Schaar and Co.
1958: 21 Feb., 433
Scientific Glass Apparatus Co.
1957: 22 Nov., 1048

FREEZING EQUIPMENT

American Hospital Supply Corp., Scientific Products Div.
1958: 25 Apr., 916
American Instrument Co., Inc.
1957: 25 Oct., 887
1958: 9 May, 1121
Fisher Scientific Co.
1957: 15 Nov., 1035
National Research Corp., NRC Equipment Corp.
1958: 26 Sept., 724; 3 Oct., 787
Virtis Co., Inc.
1957: 25 Oct., 786
1958: 21 Feb., 377

FUME HOODS

Blickman, S., Inc.
1958: 21 Feb., 436; 28 Mar., 714; 18 Apr., 889; 23 May, 1255; 20 June, 1458; 18 July, 156; 22 Aug., 424; 19 Sept., 678; 10 Oct., 853
Duralab Equipment Corp.
1958: 3 Oct., 791

FUNNELS

Corning Glass Works
1958: 3 Jan., 5
Daigger, A., & Co.
1958: 31 Jan., 255
Fischer & Porter Co.
1958: 24 Jan., 173; 21 Feb., 367
Nalge Co., Inc.
1958: 16 May, 1188

FURNACES

Consolidated Electrodynamics Corp., Rochester Div.
1958: 25 Apr., 1011
Pereny Equipment Co.
1957: 1 Nov., 940; 29 Nov., 1127; 27 Dec., 1357
Scientific Glass Apparatus Co., Inc.
1958: 12 Sept., 608

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FURNACES, SOLAR

Edmund Scientific Co.
1957: 1 Nov., 938
1958: 7 Feb., 258; 9 May, 1036; 6 June, 1310; 8 Aug., 272; 5 Sept., 493
Little, Arthur D., Inc., Engineering Div.
1957: 25 Oct., 784

FURNITURE, LABORATORY

Alberene Stone Corp.
1958: 4 Apr., 765; 2 May, 1068; 6 June, 1352; 19 Sept., 672; 17 Oct., 916
Brinkmann Instruments, Inc.
1958: 9 May, 1129; 10 Oct., 851
Custom Scientific Instruments, Inc.
1958: 9 May, 1120
Duralab Equipment Corp.
1958: 3 Oct., 791
Fisher Scientific Co.
1957: 25 Oct., 779
1958: 21 Mar., 653; 20 June, 1452; 8 Aug., 314
Graphic Systems
1957: 15 Nov., 1030
1958: 4 Apr., 764; 4 July, 40; 5 Sept., 542
Harshaw Chemical Co., Harshaw Scientific Div.
1958: 17 Oct., 908
Johns-Manville
1958: 21 Feb., 362; 11 Apr., 778; 25 Apr., 898; 9 May, 1082; 23 May, 1202; 13 June, 1362; 11 July, 50; 15 Aug., 326
Metalab Equipment Co.
1957: 25 Oct., 866
New Brunswick Scientific Co.
1957: 25 Oct., 863
1958: 6 June, 1347; 17 Oct., 916
Research Specialties Co.
1958: 12 Sept., 606
Scientific Glass Apparatus Co., Inc.
1957: 25 Oct., 880
Technicon Co.
1957: 25 Oct., 891; 6 Dec., 1207

GAS ANALYZER

Beckman Instruments, Inc., Spinco Div.
1958: 14 Feb., 310; 9 May, 1135
Cambridge Instrument Co., Inc.
1957: 6 Dec., 1152

GAS LIQUEFIER

Philips Electronics, Inc., Instruments Div.
1957: 13 Dec., 1219

GAS METER

Phipps & Bird, Inc.
1957: 1 Nov., 943
1958: 23 May, 1251

GAUGES

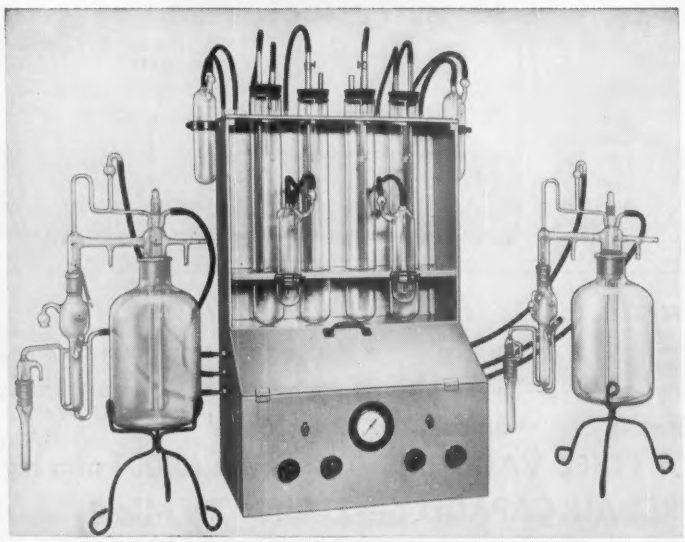
Ace Glass, Inc.
1957: 20 Dec., 1307
Consolidated Electrodynamics Corp.
1958: 17 Jan., 161; 21 Mar., 659; 19 Sept., 673; 17 Oct., 915

GLASSWARE AND ACCESSORIES

Ace Glass, Inc.
1958: 17 Jan., 160; 14 Feb., 353; 14 Mar., 607; 11 Apr., 825; 6 June, 1350; 1 Aug., 258; 26 Sept., 732
Bellco Glass, Inc.
1957: 25 Oct., 891; 6 Dec., 1192; 27 Dec., 1357
1958: 31 Jan., 251; 14 Mar., 611; 11 Apr., 822; 25 Apr., 1005; 30 May, 1295; 27 June, 1507; 25 July, 211; 29 Aug., 487; 19 Sept., 671; 26 Sept., 726
Corning Glass Works
1957: 25 Oct., 780; 6 Dec., 1153
1958: 3 Jan., 5; 14 Feb., 351; 7 Mar., 491; 11 Apr., 818; 2 May, 1079; 13 June, 1399; 5 Sept., 499; 17 Oct., 911
Fischer & Porter Co., Glass Products Div.
1957: 1 Nov., 899; 6 Dec., 1145
1958: 24 Jan., 173; 21 Feb., 367
Fish-Schurman Corp.
1957: 6 Dec., 1192
Fisher Scientific Co.
1957: 25 Oct., 779
1958: 9 May, 1128
Harshaw Chemical Co., Harshaw Scientific Div.
1958: 17 Oct., 908
Kimble Glass Co.
1958: 14 Mar., insert; 9 May, insert; 18 July, insert; 12 Sept., insert
Klett Manufacturing Co.
1957: 1 Nov., 943; 15 Nov., 1036; 29 Nov., 1129; 13 Dec., 1255; 27 Dec., 1357
1958: 3 Jan., 41; 10 Jan., 100; 17 Jan., 159; 24 Jan., 206; 31 Jan., 251; 7 Feb., 299; 21 Feb., 427; 28 Feb., 466; 7 Mar., 536; 14 Mar., 609; 21 Mar., 657; 28 Mar., 709; 4 Apr., 763; 11 Apr., 827; 18 Apr., 885; 25 Apr., 1000; 2 May, 1071; 9 May, 1129; 16 May, 1193; 23 May, 1260; 30 May, 1295; 6 June, 1354; 13

THE NEW CHEMOSTAT

A continuous culture apparatus for microorganisms complete and ready to operate



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June, 1403; 27 June, 1514; 4 July, 39; 11 July, 98; 18 July, 155; 25 July, 216; 1 Aug., 259; 8 Aug., 315; 15 Aug., 373; 22 Aug., 431; 29 Aug., 484; 5 Sept., 546; 12 Sept., 611; 19 Sept., 677; 26 Sept., 728; 3 Oct., 783; 10 Oct., 855; 17 Oct., 919

Palo Laboratory Supplies, Inc.
1958: 25 Apr., 985; 25 July, 211

Scientific Glass Apparatus Co., Inc.
1957: 25 Oct., 880

Welch, W. M., Manufacturing Co.
1958: 2 May, 1075

GLOVES, DRY BOX

Charleston Rubber Co.
1958: 2 May, 1019

GRADUATES

Daigger A., & Co.
1958: 31 Jan., 255

Nalge Co., Inc.
1958: 25 Apr., 914; 13 June, 1396

HEATERS

Central Scientific Co.
1958: 15 Aug., 367

Research Specialties Co.
1958: 21 Feb., 430

Standard Scientific Supply Corp.
1957: 22 Nov., 1083
1958: 21 Feb., 418; 23 May, 1253; 27 June, 1508

Thermo Electric Manufacturing Co.
1957: 6 Dec., 1200

HOMOGENIZERS

Lourdes Instrument Corp.
1958: 7 Mar., 534

Microchemical Specialties Co.
1957: 8 Nov., 985

Tri-R Instruments
1957: 25 Oct., 874

HOT PLATES

Research Specialties Co.
1958: 21 Feb., 430

Thermo Electric Manufacturing Co.
1957: 8 Nov., 986

HOODS

Alberene Stone Corp.
1958: 14 Mar., 605

Lennard, P. M., Co., Inc.
1958: 25 Apr., 993

HUMIDITY CONTROLLER

Daigger, A., and Co.
1957: 25 Oct., 798

Niagara Blower Co.
1957: 13 Dec., 1258

HUMIDITY GAUGE

Daigger, A., and Co.
1957: 25 Oct., 798

ILLUMINATORS

American Optical Co., Instrument Div.
1957: 8 Nov., 992
1958: 24 Jan., 208; 28 Mar., 720; 2 May, 1080; 16 May, 1200; 11 July, 104; 22 Aug., 436

Bausch & Lomb Optical Co.
1958: 15 Aug., 336

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INCUBATORS

American-Lincoln Incubator Co.
1958: 17 Oct., 918
Electric Hotpack Co.
1958: 17 Oct., 909
New York Laboratory Supply Co., Inc.
1958: 27 June, 1513

ISOLATORS

American Sterilizer Co.
1958: 25 Apr., 901; 15 Aug., 333

KNIVES

Scott-Mitchell House, Inc.
1958: 26 Sept., 730

KYMOGRAPHS

Phipps & Bird, Inc.
1957: 6 Dec., 1209
1958: 9 May, 1123; 16 May, 1199; 5 Sept., 551; 12 Sept., 611

LABELS, TIME

Professional Tape Co., Inc.
1958: 12 Sept., 604; 17 Oct., 912

LABORATORY CLAMP

New York Laboratory Supply Co., Inc.
1958: 26 Sept., 733

LABORATORY EQUIPMENT, NUCLEONIC

Anton Electronic Laboratories, Inc.
1958: 12 Sept., 619
Atomic Accessories, Inc.
1958: 17 Jan., 162
Baird-Atomic, Inc.
1958: 14 Feb., 354
Blickman, S., Inc.
1958: 21 Feb., 436
Budd Co., Nuclear Systems Div.
1958: 6 June, 1345
Eldorado Electronics
1958: 14 Feb., 350; 14 Mar., 607; 13 June, 1403
General Dynamics Corp., General Atomic Div.
1958: 18 July, 109
Nuclear-Chicago Corp.
1957: 25 Oct., 799; 27 Dec., 1315
1958: 10 Jan., 52, 53; 28 Feb., 443; 18 July, 168; 29 Aug., 492; 26 Sept., 740
Nuclear Science and Engineering Corp.
1958: 7 Mar., 542
Packard Instrument Co., Inc.
1958: 15 Aug., 334
Technical Measurement Corp.
1958: 11 July, 58; 5 Sept., 502
Tracerlab, Inc.
1958; 22 Aug., 425

LABORATORY JACK

Central Scientific Co.
1957: 25 Oct., 771
1958: 8 Aug., 313

LABORATORY MILL

Thomas, Arthur H., Co.
1957: 29 Nov., 1136

LABORATORY PRESS

Lee Engineering Co.
1958: 15 Aug., 372; 29 Aug., 486; 12 Sept., 612; 26 Sept., 730

LABORATORY SUPPLIES

Ace Glass, Inc.
1958: 14 Feb., 353; 14 Mar., 607; 4 July, 36; 26 Sept., 732
Busse Hospital Products
1957: 25 Oct., 872
Central Scientific Co.
1958: 26 Sept., 728
Clay-Adams, Inc.
1957: 22 Nov., 1077
Corning Glass Works
1958: 7 Mar., 491
Daigger, A., & Co.
1958: 31 Jan., 255
Fisher Scientific Co.
1958: 21 Mar., 653; 10 Oct., 852
Foringer & Co., Inc.
1958: 25 Apr., 1015
Greiner, Emil, Co.
1958: 12 Sept., 561
Harshaw Chemical Co., Harshaw Scientific Div.
1958: 17 Oct., 908
Kennametal, Inc.
1958: 7 Mar., 546
Linbro Chemical Co.
1957: 25 Oct., 855
Nalge Co., Inc.
1957: 15 Nov., 1028
1958: 25 Apr., 914
New York Laboratory Supply Co., Inc.
1958: 7 Mar., 539
Thomas, Arthur H., Co.
1957: 6 Dec., 1215; 13 Dec., 1264
1958: 10 Jan., 104
United States Testing Co., Inc.
1957: 25 Oct., 859
1958: 7 Mar., 497; 27 June, 1467
Will Corp.
1957: 15 Nov., 1031
1958: 16 May, 1191; 18 July, 157

LAMPS

American Speedlight Corp.
1958: 25 Apr., 988
Artisto Grid Lamp Products, Inc.
1957: 25 Oct., 886
Bausch & Lomb Optical Co.
1957: 27 Dec., 1354
1958: 31 Jan., 214
Edmund Scientific Co.
1957: 6 Dec., 1200
1958: 11 Apr., 831
Leitz, E., Co.
1958: 17 Jan., 107; 14 Feb., 309
Standard Scientific Supply Corp.
1958: 17 Jan., 164
Ultra-Violet Products, Inc.
1957: 25 Oct., 866
1958: 7 Mar., 534; 18 July, 154; 15 Aug., 372; 19 Sept., 668
United Scientific Co., Unitron Instrument Div.
1958: 26 Sept., 739

LATTICE HARDWARE

Lee Engineering Co.
1958: 22 Aug., 430; 5 Sept., 542; 19 Sept., 678

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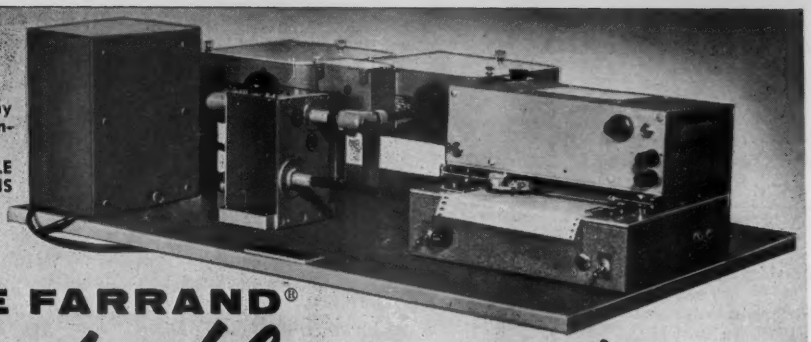

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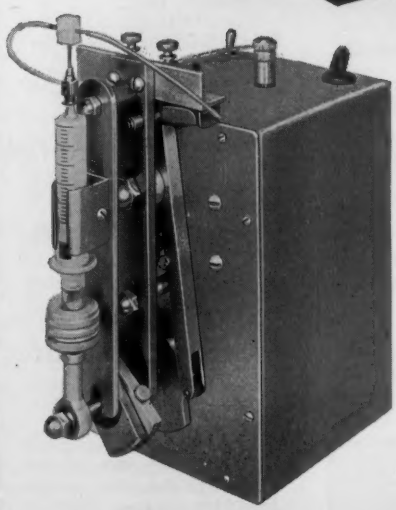

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LEAK DETECTORS

Consolidated Electrodynamics Corp., Rochester Div.
1958: 17 Jan., 161

LIGHT ADAPTERS

American Speedlight Corp.
1957: 25 Oct., 878; 6 Dec., 1196

MACROPHOTOGRAPHIC EQUIPMENT

American Speedlight Corp.
1957: 25 Oct., 878; 6 Dec., 1196
Brinkmann Instruments, Inc.
1958: 16 May, 1193
Hofmann, Alfred, & Co.
1957: 25 Oct., 883

MACROSCOPES

Bausch & Lomb Optical Co.
1957: 1 Nov., 938; 6 Dec., 1158
1958: 12 Sept., 568

MAGNIFIERS

Edmund Scientific Co.
1958: 3 Jan., 47; 7 Mar., 496
Novel Manufacturing Co.
1958: 10 Jan., 99; 21 Feb., 427
Scott-Mitchell House, Inc.
1958: 3 Jan., 43

MANOMETERS

Will Corp., Bronwill Scientific Div.
1958: 14 Feb., 349; 16 May, 1195; 19 Sept., 674; 3 Oct., 784

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MELTING POINT APPARATUS

Fisher Scientific Co.
1958: 11 July, 96
Thomas, Arthur H., Co.
1957: 25 Oct., 895
1958: 4 July, 48

MERCURY VAPOR DETECTORS

Kruger, Harold, Instruments
1958: 15 Aug., 368

MICROANALYSIS EQUIPMENT

Ainsworth, Wm., & Sons, Inc.
1958: 18 July, 153
Aloe, A. S., Co., Aloe Scientific Div.
1957: 1 Nov., 935
1958: 3 Jan., 46; 4 Apr., 763; 2 May, 1071; 4 July, 43; 1 Aug., 259; 5 Sept., 546
American Optical Co., Instrument Div.
1958: 19 Sept., 684
Brinkmann Instruments, Inc.
1957: 1 Nov., 937
1958: 25 Apr., 1009
Central Scientific Co.
1958: 8 Aug., 313
Clay-Adams, Inc.
1957: 25 Oct., 879
Exact Weight Scale Co.
1958: 2 May, 1072; 8 Aug., 317
Leitz, E., Inc.
1958: 4 July, 47
Mettler Instrument Corp.
1958: 12 Sept., 565
Micro-Metric Instrument Co.
1957: 25 Oct., 875
Stoelting, C. H., Co.
1958: 11 Apr., 827; 23 May, 1253; 18 July, 155; 26 Sept., 736

MICROBIOLOGICAL EQUIPMENT

Beckman Instruments, Inc., Spinco Div.
1958: 26 Sept., 686
Bellco Glass, Inc.
1958: 27 June, 1507; 25 July, 211; 29 Aug., 487; 19 Sept., 671; 26 Sept., 726
Blickman, S., Inc.
1957: 13 Dec., 1263
Delmar Scientific Laboratories
1957: 6 Dec., 1190
1958: 21 Feb., 423; 25 Apr., 998
Fisher Scientific Co.
1958: 17 Jan., 163
Instrument & Development Products Co., Inc.
1958: 13 June, 1398
Lennard, P. M., Co., Inc.
1957: 25 Oct., 884; 6 Dec., 1205
Technical Instrument Co.
1958: 21 Feb., 427
Thomas, Arthur H., Co.
1958: 9 May, 1136

MICROBIOLOGICAL MEDIA

Clinton Laboratories
1957: 25 Oct., 889
1958: 21 Feb., 433
Colorado Serum Co.
1957: 25 Oct., 869; 15 Nov., 1026
1958: 21 Feb., 415; 25 Apr., 999; 16 May, 1196; 13 June, 1397
Difco Laboratories
1957: 25 Oct., 857; 22 Nov., 1077; 20 Dec., 1303
1958: 17 Jan., 159; 14 Feb., 355; 14 Mar., 609; 11 Apr., 823; 2 May, 1071; 30

May, 1300; 25 July, 215; 22 Aug., 431; 19 Sept., 675; 17 Oct., 919

Hyland Laboratories
1957: 25 Oct., 883
1958: 17 Jan., 157; 21 Feb., 425; 7 Mar., 537; 25 Apr., 1001; 15 Aug., 370

MICROCARDS

Microcard Corp.
1958: 5 Sept., 541; 3 Oct., 787

MICROMANIPULATORS

Aloe, A. S., Co., Aloe Scientific Div.
1957: 1 Nov., 935
1958: 3 Jan., 46; 2 May, 1071; 5 Sept., 546

American Optical Co., Instrument Div.
1958: 19 Sept., 684

Brinkmann Instruments, Inc.
1958: 25 Apr., 1009

Leitz, E., Inc.
1958: 4 July, 47

Stoelting, C. H., Co.
1958: 11 Apr., 827; 23 May, 1253; 18 July, 155; 26 Sept., 736

MICROMETERS

Decker Corp.
1958: 21 Feb., 365

MICRORADIOGRAPHIC EQUIPMENT

Philips Electronics, Inc.
1957: 25 Oct., 782

MICROSCOPES

American Optical Co., Instrument Div.
1957: 25 Oct., 896; 22 Nov., 1088; 6 Dec., 1216
1958: 3 Jan., 48; 31 Jan., 256; 28 Feb., 488; 14 Mar., 616; 18 Apr., 896; 30 May, 1304; 27 June, 1520; 8 Aug., 324; 5 Sept., 556

Bausch & Lomb Optical Co.
1957: 25 Oct., 804; 20 Dec., 1270
1958: 17 Jan., 114; 28 Feb., 450; 28 Mar., 674; 25 Apr., 934; 6 June, 1316; 4 July, 6; 29 Aug., 444; 26 Sept., 692

Brinkmann Instruments, Inc.
1957: 13 Dec., 1257
1958: 26 Sept., 733

Edmund Scientific Co.
1958: 3 Oct., 795

Graf-Apsco Co.
1957: 25 Oct., 891
1958: 12 Sept., 609; 26 Sept., 736; 17 Oct., 910

Hacker, William J., & Co., Inc.
1958: 25 July, 172

Leitz, E., Inc.
1957: 25 Oct., 772; 8 Nov., 948; 22 Nov., 1044; 6 Dec., 1146; 20 Dec., 1310
1958: 3 Jan., 4; 14 Mar., 559; 28 Mar., 707; 25 Apr., 906; 9 May, 1087; 23 May, 1208; 30 May, 1267; 1 Aug., 224; 29 Aug., 442; 12 Sept., 564; 19 Sept., 624

Monroe Microscope Service
1958: 22 Aug., 430

Olympus Optical Instrument Co.
1957: 25 Oct., 796; 6 Dec., 1197

United Scientific Co., Unitron Instrument Div.
1957: 25 Oct., 781; 29 Nov., 1135; 13 Dec., 1222
1958: 7 Mar., 493; 21 Mar., 652; 11

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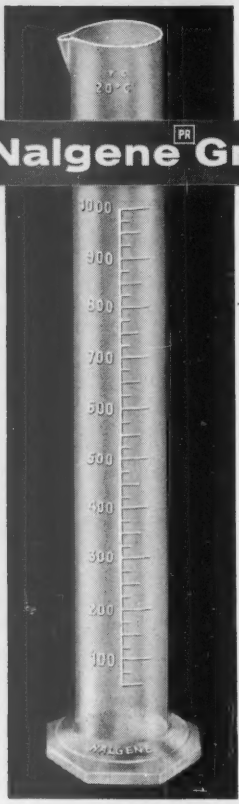

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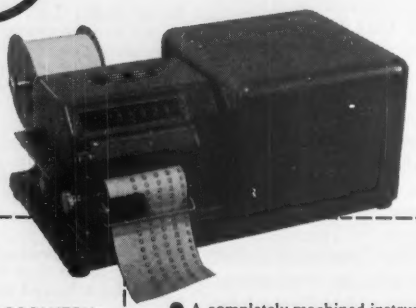

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Apr., 819; 9 May, 1125; 5 Sept., 547; 10 Oct., 856

Wild Heerbrugg Instruments, Inc.
1957: 25 Oct., 865; 15 Nov., 1035; 6 Dec., 1198
1958: 10 Jan., 95; 24 Jan., 202; 21 Feb., 434; 10 Oct., 853

Zeiss, Carl, Inc.
1957: 8 Nov., 991; 22 Nov., 1049
1958: 25 Apr., 928; 11 July, 56; 8 Aug., 323; 5 Sept., 501

MICROSCOPES, ELECTRON

Erb & Gray Scientific Co.
1958: 21 Feb., 421; 9 May, 1129; 8 Aug., 315

Philips Electronics, Inc.
1957: 25 Oct., 782; 8 Nov., 950; 22 Nov., 1047

Siemens & Halske
1958: 24 Jan., 197; 7 Mar., 495; 28 Mar., 666; 25 Apr., 912

MICROSCOPES, PHASE

American Optical Co., Instrument Div.
1957: 20 Dec., 1312
1958: 4 Apr., 776; 25 July, 220

United Scientific Co., Unitron Instrument Div.
1957: 25 Oct., 781; 15 Nov., 1034; 29 Nov., 1135
1958: 18 Apr., 835; 27 June, 1469; 25 July, 171; 17 Oct., 917

MICROSCOPES, STEREO

American Optical Co., Instrument Div.
1957: 25 Oct., 896; 6 Dec., 1216
1958: 14 Feb., 360; 2 May, 1080; 16 May, 1200; 13 June, 1406; 11 July, 104

Bausch & Lomb Optical Co.
1957: 22 Nov., 1052
1958: 14 Feb., 314

Edmund Scientific Co.
1957: 1 Nov., 938; 6 Dec., 1200
1958: 3 Jan., 47; 11 Apr., 831; 9 May, 1086

Monroe Microscope Service
1958: 25 Apr., 1002

United Scientific Co., Unitron Instrument Div.
1958: 14 Feb., 350; 23 May, 1254; 19 Sept., 668

MICROSCOPES, STUDENT

Bausch & Lomb Optical Co.
1958: 14 Mar., 564; 11 Apr., 786; 23 May, 1212

Edmund Scientific Co.
1958: 7 Feb., 258; 7 Mar., 496; 11 July, 103; 8 Aug., 272; 5 Sept., 498

Graf-Apsco Co.
1957: 6 Dec., 1192
1958: 5 Sept., 542; 19 Sept., 675

Leitz, E., Inc.
1957: 22 Nov., 1044; 20 Dec., 1310
1958: 3 Jan., 4; 25 Apr., 906; 23 May, 1208

United Scientific Co., Unitron Instrument Div.
1958: 14 Mar., 606; 4 Apr., 764; 2 May, 1070; 12 Sept., 612

MICROSCOPES, X-RAY

General Electric Co.
1958: 21 Feb., 431; 25 Apr., 990; 20 June, 1456; 22 Aug., 428

MICROSCOPE ACCESSORIES

American Optical Co., Instrument Div.
1957: 8 Nov., 992
1958: 24 Jan., 208; 31 Jan., 256; 28 Feb., 488; 14 Mar., 616; 28 Mar., 720; 4 Apr., 776; 2 May, 1080; 16 May, 1200; 11 July, 104; 22 Aug., 436
Bausch & Lomb Optical Co.
1958: 17 Jan., 114; 15 Aug., 336
Busse Hospital Products
1957: 25 Oct., 872
Custom Scientific Instruments, Inc.
1958: 12 Sept., 606
Dell Optics Co., Ltd.
1958: 21 Feb., 416; 21 Mar., 652; 18 Apr., 889
Hacker, William J., & Co., Inc.
1958: 14 Mar., 611; 25 July, 172
Leitz, E., Inc.
1958: 14 Feb., 309; 6 June, 1359
Monroe Microscope Service
1957: 25 Oct., 881
Thomas, Arthur H., Co.
1957: 25 Oct., 895
United Scientific Co., Unitron Instrument Div.
1958: 21 Feb., 371; 15 Aug., 331; 26 Sept., 739; 17 Oct., 917

MICROTOMES AND ACCESSORIES

Aloe, A. S., Co., Aloe Scientific Div.
1957: 25 Oct., 857; 6 Dec., 1195
1958: 7 Feb., 303; 7 Mar., 541
American Hospital Supply Corp.
1958: 25 Apr., 916
Brinkmann, C. A., & Co., Inc.
1958: 11 Apr., 823
Hacker, William J., & Co., Inc.
1957: 25 Oct., 861
1958: 7 Mar., 539
Leitz, E., Inc.
1958: 11 Apr., 783
Monroe Microscope Service
1957: 25 Oct., 881
Sorvall, Ivan, Inc.
1957: 25 Oct., 791; 6 Dec., 1138
1958: 26 Sept., 690

MIXERS

Laboratory Glass and Instrument Corp.
1957: 25 Oct., 885
1958: 25 July, 170; 12 Sept., 560
Lourdes Instrument Corp.
1957: 25 Oct., 775
1958: 24 Jan., 171
Sorvall, Ivan, Inc.
1958: 20 June, 1415; 26 Sept., 690

MOLECULAR MODEL SET

Smith, Arthur F., Co.
1958: 10 Jan., 94
Standard Scientific Supply Co.
1958: 18 July, 152

MONOCHROMATORS

Bausch & Lomb Optical Co.
1958: 20 June, 1418
Biddle, James G., Co.
1958: 25 Oct., 885
Farrand Optical Co., Inc.
1958: 16 May, 1196; 18 July, 159
Kahl Scientific Instrument Corp.
1957: 25 Oct., 872
Photovolt Corp.
1957: 15 Nov., 1033; 27 Dec., 1357
1958: 17 Jan., 165; 14 Feb., 348; 4 Apr., 763; 2 May, 1067; 6 June, 1349; 4 July, 43; 8 Aug., 313; 3 Oct., 783

NEPHELOMETERS

Coleman Instruments, Inc.
1957: 29 Nov., 1130
1958: 25 July, 209; 26 Sept., 735

OPTICAL CRYSTALS

Dell Optics Co., Ltd.
1958: 21 Feb., 416; 21 Mar., 652
Harshaw Chemical Co.
1957: 25 Oct., 877; 15 Nov., 1033; 6 Dec., 1211
1958: 10 Jan., 97; 21 Feb., 421; 21 Mar., 651; 18 Apr., 885; 16 May, 1189, 15 Aug., 367; 19 Sept., 671
Isomet Corp.
1958: 21 Feb., 419

OPTICAL INSTRUMENTS

Gurley, W. & L. E.
1958: 17 Oct., 918

OSCILLATORS, SONIC

Raytheon Manufacturing Co.
1957: 25 Oct., 777; 15 Nov., 1040
1958: 11 Apr., 781; 25 Apr., 907; 2 May, 1022; 9 May, 1085; 16 May, 1141; 6 June, 1313; 10 Oct., 798

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OSCILLOSCOPES

Sanborn Co.
1957: 25 Oct., 793; 1 Nov., 898; 22 Nov., 1045
1958: 14 Mar., facing 584

OVENS

Ace Glass, Inc.
1957: 25 Oct., 850
American Instrument Co., Inc.
1958: 13 June, 1365
Brinkmann Instruments, Inc.
1958: 17 Jan., 109
Central Scientific Co.
1957: 25 Oct., 771
1958: 22 Aug., 431
Fisher Scientific Co.
1958: 11 Apr., 826
Pereny Equipment Co.
1957: 29 Nov., 1127
Schaar and Co.
1957: 8 Nov., 985

PETRI DISHES

Thomas, Arthur H., Co.
1958: 9 May, 1136

pH INDICATORS

Advanced Instruments, Inc.
1957: 25 Oct., 856
Analytical Measurements, Inc.
1958: 7 Feb., 296; 25 Apr., 1008

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Beckman Instruments, Inc., Scientific Instruments Div.
1958: 4 Apr., 775; 11 July, 55
Brinkmann Instruments, Inc.
1958: 6 June, 1354
Cambridge Instrument Co., Inc.
1957: 6 Dec., 1152
1958: 21 Feb., 424
Coleman Instruments, Inc.
1958: 9 May, 1127; 11 July, 95

PHOTOMETERS

Advanced Instruments, Inc.
1957: 25 Oct., 856
Baird-Atomic, Inc.
1958: 17 Oct., 920
Eldorado Electronics
1957: 25 Oct., 866; 8 Nov., 986; 13 Dec., 1259
1958: 10 Jan., 95; 11 Apr., 818; 4 Apr., 766
Farrand Optical Co., Inc.
1958: 25 Apr., 987; 26 Sept., 724
Fisher Scientific Co.
1957: 13 Dec., 1258
1958: 21 Feb., 432
Kahl Scientific Instrument Corp.
1957: 25 Oct., 872
Metro Industries
1957: 25 Oct., 877
Perkin-Elmer Corp., Instrument Div.
1957: 25 Oct., 789
Photovolt Corp.
1957: 1 Nov., 943; 20 Dec., 1303
1958: 24 Jan., 199; 7 Mar., 541; 25 Apr., 997; 16 May, 1189

PHOTOMICROGRAPHIC EQUIPMENT

American Optical Co., Instrument Div.
1958: 3 Oct., 796
American Speedlight Corp.
1957: 25 Oct., 878; 6 Dec., 1196
Bausch & Lomb Optical Co.
1957: 1 Nov., 938
1958: 18 July, 114; 29 Aug., 444; 26 Sept., 692
Brinkmann Instruments, Inc.
1958: 16 May, 1193
Central Scientific Co.
1957: 15 Nov., 1039; 13 Dec., 1218
1958: 10 Jan., 103; 21 Feb., 368; 28 Mar., 719; 4 Apr., 723
Electro-Mechanical Development Co.
1958: 24 Jan., 206
Hofmann, Alfred, & Co.
1957: 25 Oct., 883
Leitz, E., Inc.
1957: 25 Oct., 772; 8 Nov., 948
Photovolt Corp.
1957: 1 Nov., 943; 20 Dec., 1303
1958: 24 Jan., 199; 7 Mar., 541; 25 Apr., 997; 16 May, 1189
United Scientific Co., Unitron Instrument Div.
1957: 25 Oct., 781; 29 Nov., 1135
1958: 7 Feb., 297; 16 May, 1190; 25 July, 171; 17 Oct., 917
Zeiss, Carl, Inc.
1957: 25 Oct., 787
1958: 21 Feb., 375; 21 Mar., 620; 11 July, 56

PIPETTES AND ACCESSORIES

American Hospital Supply Corp., Scientific Products Div.
1958: 15 Aug., 329

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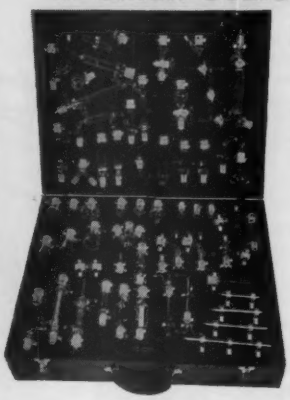

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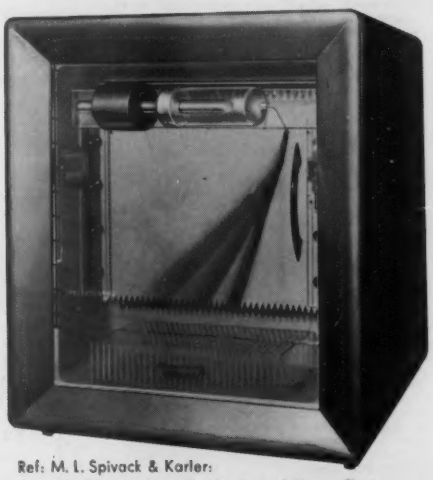

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Ref: M. L. Spivack & Karler:
Journal of Immunology, Purification of Plague Toxin, Vol. 80 No. 6, pp 441-445, June 58. Patents Applied for.

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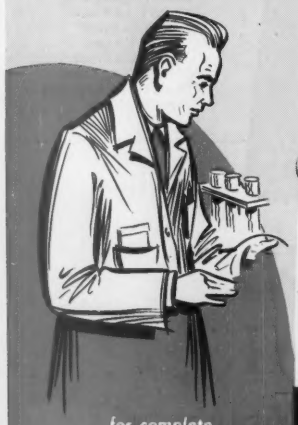

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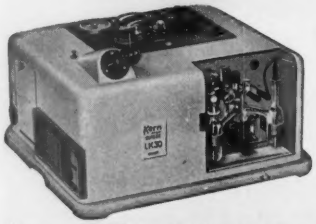

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Clay-Adams, Inc.
1957: 25 Oct., 879
Corning Glass Works
1958: 2 May, 1079; 5 Sept., 499
Fischer & Porter Co., Glass Products Div.
1957: 1 Nov., 899; 6 Dec., 1145
Fisher Scientific Co.
1958: 12 Sept., 610
Nalge Co., Inc.
1958: 17 Jan., 162; 21 Feb., 420; 8 Aug., 318
National Instrument Co.
1957: 25 Oct., 889
Palo Laboratory Supplies, Inc.
1958: 25 July, 211
Phipps & Bird, Inc.
1957: 25 Oct., 863
Research Specialties Co.
1957: 15 Nov., 1030
1958: 3 Jan., 44; 28 Feb., 446
Thomas, Arthur H., Co.
1958: 11 Apr., 832; 12 Sept., 620

POLARIMETERS

Fish-Schurman Corp.
1957: 25 Oct., 889
Kern Co.
1957: 25 Oct., 857
1958: 21 Feb., 423
Leitz, E., Inc.
1958: 26 Sept., 689
Zeiss, Carl, Inc.
1957: 22 Nov., 1049; 6 Dec., 1150
1958: 21 Mar., 620; 16 May, 1138; 8 Aug., 323

POLAROGRAPHS

Sargent, E. H., & Co.
1957: 25 Oct., 797
1958: 24 Jan., 170; 13 June, 1363
Standard Scientific Supply Corp.
1958: 21 Mar., 618

POWER PACKS

Electronic Measurements Co., Inc.
1957: 25 Oct., 865; 6 Dec., 1206

PRESSURE APPARATUS

Parr Instrument Co.
1957: 25 Oct., 871

PROJECTORS

Bausch & Lomb Optical Co.
1957: 1 Nov., 938; 6 Dec., 1158; 27 Dec., 1354
1958: 31 Jan., 214; 18 July, 114; 12 Sept., 568; 10 Oct., 808
Hofmann, Alfred, & Co.
1957: 25 Oct., 883
Leitz, E., Inc.
1958: 31 Jan., 211; 28 Feb., 447; 20 June, 1413; 10 Oct., 801
Zeiss, Carl, Inc.
1957: 25 Oct., 787

PUMPS

Harvard Apparatus Co., Inc.
1958: 23 May, 1259
New Brunswick Scientific Co.
1958: 11 July, 94
Phipps & Bird, Inc.
1958: 18 Apr., 886; 4 July, 39; 18 July, 159; 26 Sept., 728
Scott-Mitchell House, Inc.
1958: 3 Jan., 43

Sigmamotor, Inc.
1958: 7 Mar., 541; 5 Sept., 541

PUMPS, VACUUM

Central Scientific Co.
1957: 25 Oct., 770
1958: 20 June, 1455; 18 July, 167; 19 Sept., 677
Consolidated Electrodynamics Corp., Rochester Div.
1958: 17 Jan., 161; 25 Apr., 1011; 16 May, 1187; 15 Aug., 369; 19 Sept., 673
Little, Arthur D., Inc., Engineering Div.
1957: 25 Oct., 784
National Research Corp., NRC Equipment Corp.
1958: 14 Feb., 348; 11 July, 98; 26 Sept., 724; 3 Oct., 787
Schaar and Co.
1958: 7 Mar., 536
Standard Scientific Supply Corp.
1957: 6 Dec., 1202
1958: 15 Aug., 374
Welch, W. M., Manufacturing Co.
1958: 6 June, 1349; 4 July, 37; 1 Aug., 261

PYROMETERS

Cambridge Instrument Co., Inc.
1957: 6 Dec., 1152

RADIATION COUNTERS

Anton Electronic Laboratories, Inc.
1958: 12 Sept., 619
Applied Physics Corp.
1957: 6 Dec., 1193
Atomic Accessories, Inc.
1957: 25 Oct., 890
Baird-Atomic, Inc.
1957: 25 Oct., 774; 29 Nov., 1131
1958: 14 Feb., 354
Borg-Warner Corp., BJ Electronics
1958: 18 Apr., 887
Cambridge Instrument Co.
1957: 25 Oct., 869
Nuclear-Chicago Corp.
1957: 25 Oct., 799; 29 Nov., 1090; 27 Dec., 1315
1958: 21 Mar., 664; 25 Apr., 900; 20 June, 1464; 29 Aug., 492; 17 Oct., 924
Nuclear Corporation of America, Inc., NRD Instrument Co.
1957: 25 Oct., 790
Nuclear Measurements Corp.
1958: 27 June, 1512; 25 July, 208
Packard Instrument Co.
1957: 25 Oct., 882; 6 Dec., 1201
1958: 21 Feb., 428; 4 Apr., 767; 25 Apr., 1016; 23 May, 1210; 18 July, 112; 15 Aug., 334; 10 Oct., 806
Philips Electronics, Inc.
1957: 25 Oct., 782; 8 Nov., 950; 22 Nov., 1047
Technical Measurement Corp.
1958: 7 Mar., 494; 16 May, 1144; 27 June, 1470; 8 Aug., 276; 5 Sept., 502
Tracerlab, Inc.
1957: 20 Dec., 1268
1958: 24 Jan., 202; 18 Apr., 891; 19 Sept., 679

RADIATION HAZARD CONTROLS

Controls for Radiation, Inc.
1958: 10 Jan., 50; 9 May, 1124; 23 May, 1251; 13 June, 1399; 18 July, 164; 10 Oct., 848

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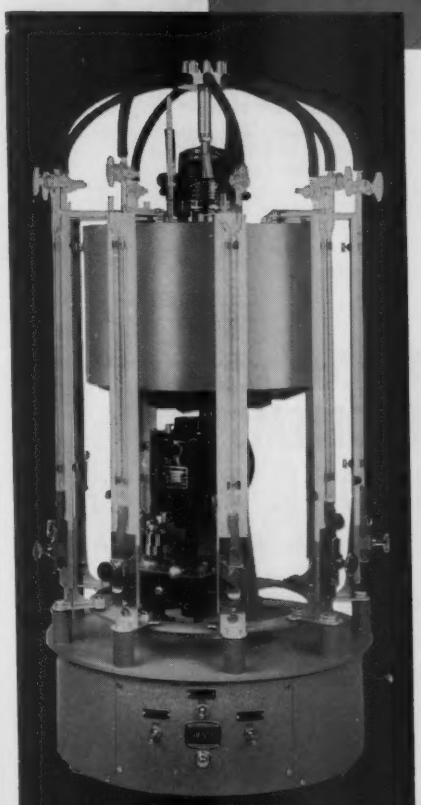

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Lindsay Chemical Co.
1957: 15 Nov., 994

RARE GASES

Union Carbide Corp., Linde Co. Div.
1958: 7 Mar., 543; 2 May, 1073

RECORDERS, GRAPHIC

Foringer & Co., Inc.
1958: 25 Apr., 1015
Gilson Medical Electronics
1958: 18 July, 164; 15 Aug., 371; 26 Sept., 726
Stoelting, C. H., Co.
1958: 15 Aug. 371
Harvard Apparatus Co., Inc.
1958: 24 Jan. 204
Mandrel Industries, Inc.
1958: 2 May, 1066
Photovolt Corp.
1957: 25 Oct., 877; 8 Nov., 985; 6 Dec., 1205
1958: 31 Jan., 251; 21 Feb., 433; 21 Mar. 657; 18 Apr., 885; 23 May, 1251; 20 June, 1455; 18 July, 167; 22 Aug., 431; 26 Sept., 731
Sanborn Co.
1958: 11 Apr., 780
Sargent, E. H., & Co.
1957: 25 Oct., 797
1958: 21 Feb., 379; 11 July, 54; 5 Sept., 555
Stoelting, C. H., Co.
1957: 25 Oct., 881; 1 Nov., 937; 15 Nov., 1029; 29 Nov., 1129
1958: 28 Mar., 713; 25 Apr., 999; 20 June, 1449

RECORDING EQUIPMENT, BIOPHYSICAL

American Electronic Laboratories, Inc.
1957: 25 Oct., 885
Sanborn Co., Medical Div.
1957: 25 Oct., 793; 1 Nov., 898; 22 Nov., 1045; 6 Dec., 1149; 20 Dec., 1269
1958: 17 Jan., 111; 6 June, 1314; 18 July, facing 137; 15 Aug., 327; 12 Sept., 562
Technical Measurement Corp.
1958: 11 July, 58
Yellow Springs Instrument Co., Inc.
1957: 6 Dec., 1199

REFRACTOMETERS

Leitz, E., Inc.
1958: 26 Sept., 689
Zeiss, Carl, Inc.
1957: 22 Nov., 1049

RESIN REACTION APPARATUS

Scientific Glass Apparatus Co.
1958: 13 June, 1402

ROTORS

Beckman Instruments, Inc., Spinco Div.
1957: 25 Oct., 785; 6 Dec., 1147
1958: 17 Oct., 862
Lourdes Instrument Corp.
1958: 25 Apr., 924
Sorvall, Ivan, Inc.
1957: 25 Oct., 791

SCALES

Exact Weight Scale Co.
1958: 28 Mar., 715; 18 Apr., 883; 2 May, 1072
National Instrument Co.
1957: 25 Oct., 889
Welch, W. M., Manufacturing Co.
1958: 4 Apr., 769

SHAKERS

Central Scientific Co.
1957: 25 Oct., 770
Laboratory Glass and Instrument Corp.
1957: 25 Oct., 885
1958: 25 Apr., 908; 12 Sept., 560
New Brunswick Scientific Co.
1958: 2 May, 1075; 9 May, 1123; 23 May, 1257; 20 June, 1449; 25 July, 216; 5 Sept., 551
Parr Instrument Co.
1957: 25 Oct., 871
Research Specialties Co.
1957: 25 Oct., 855
1958: 25 Apr., 995
Schaar and Co.
1957: 25 Oct., 871

SHOCK TESTING APPARATUS

Consolidated Electrodynamics Corp., Rochester Div.
1958: 20 June, 1459

SINKS

Alberene Stone Corp.
1958: 4 Apr., 765; 19 Sept., 672

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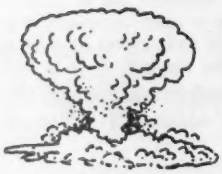

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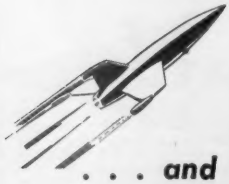

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SKELETON MODEL

Andrew Technical Co.
1958: 7 Feb., 297
Welch, W. M., Manufacturing Co.
1958: 7 Feb., 303; 3 Oct., 783

SLIDE RULES

Garfield, Oliver, Co., Inc.
1958: 21 Feb., 428; 9 May, 1120

SPECTROMETERS

Biddle, James G., Co.
1957: 25 Oct., 885
Kahl Scientific Instrument Corp.
1957: 25 Oct., 872
Packard Instrument Co.
1957: 15 Nov., 1030; 6 Dec., 1201
1958: 7 Feb., 300; 21 Feb., 428; 25 Apr., 1004; 2 May, 1074; 13 June, 1368; 1 Aug., 262; 15 Aug., 334; 19 Sept., 628; 10 Oct., 806
Perkin-Elmer Corp., Instrument Div.
1958: 18 Apr., 895
Polarad Electronics Corp., Scientific Instruments Div.
1958: 21 Feb., 424
Technical Measurement Corp.
1958: 25 Apr., 932
Varian Associates, Instrument Div.
1957: 27 Dec., 1358
1958: 14 Feb., 306; 25 Apr., 922; 20 June, 1463; 15 Aug., 332; 19 Sept., 623

SPECTROPHOTOMETERS AND ACCESSORIES

Applied Physics Corp.
1957: 25 Oct., 873
1958: 21 Feb., 435; 7 Mar., 535; 25 July, 213
Axler Associates, Inc.
1958: 25 Apr., 1002
Beckman Instruments, Inc., Scientific Instruments Div.
1957: 25 Oct., 801
1958: 7 Mar., 551; 2 May, 1018; 12 Sept., 615
Coleman Instruments, Inc.
1957: 15 Nov., 1034; 13 Dec., 1259
1958: 25 Apr., 1007; 20 June, 1453; 22 Aug., 429; 2 Sept., 607
Gilson Medical Electronics
1958: 29 Aug., 484
New York Laboratory Supply Co., Inc.
1958: 25 Apr., 995
Perkin-Elmer Corp., Instrument Div.
1957: 25 Oct., 789; 22 Nov., 1046
1958: 17 Jan., 167; 7 Mar., 492; 23 May, 1204; 15 Aug., 379; 5 Sept., 496
Will Corp.
1958: 18 July, 157
Zeiss, Carl, Inc.
1958: 17 Jan., 168; 6 June, 1312

SPECTROSCOPES

Bausch & Lomb Optical Co.
1957: 6 Dec., 1158
1958: 12 Sept., 568
Borg-Warner Corp., BJ Electronics
1958: 26 Sept., 734
Edmund Scientific Co.
1958: 3 Oct., 795
Leitz, E., Inc.
1958: 26 Sept., 689
Varian Associates, Instrument Div.
1957: 29 Nov., 1091
Zeiss, Carl, Inc.
1958: 21 Mar., 620; 8 Aug., 323

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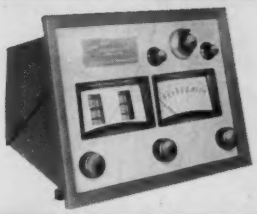

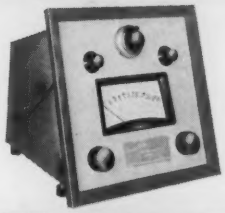

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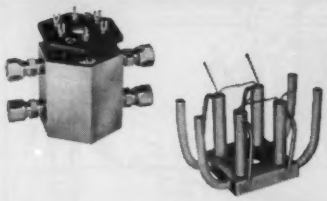

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STERILIZER EQUIPMENT

American Sterilizer Co., Scientific Div.
1958: 7 Feb., 259; 28 Mar., 669; 20 June, 1411; 18 July, 107; 22 Aug., 382
Wilmot Castle Co.
1957: 25 Oct., 854
1958: 6 June, 1308, 1309; 4 July, 2; 5 Sept., 497

STETHOSCOPES, AMPLIFYING

Sanborn Co.
1957: 25 Oct., 793; 1 Nov., 898

STILLS

Consolidated Electrodynamics Corp., Rochester Div.
1958: 21 Feb., 429; 18 July, 161
Smith, Arthur F., Co.
1957: 25 Oct., 792

STIRRERS

Ace Glass, Inc.
1957: 22 Nov., 1082
1958: 17 Jan., 160
Central Scientific Co.
1958: 13 June, 1403; 3 Oct., 785
Palo Laboratory Supplies, Inc.
1958: 11 Apr., 824
Parr Instrument Co.
1957: 25 Oct., 871
Tri-R Instruments
1957: 25 Oct., 874
Welch, W. M., Manufacturing Co.
1958: 3 Jan., 46

TELESCOPES

Edmund Scientific Co.
1957: 1 Nov., 938; 6 Dec., 1200
1958: 3 Jan., 47; 7 Feb., 258; 7 Mar., 496; 11 Apr., 831; 9 May, 1086; 6 June, 1310; 11 July, 103; 8 Aug., 272; 5 Sept. 498; 3 Oct., 795
Fecker, J. W., Inc.
1957: 25 Oct., 870; 22 Nov., 1080; 6 Dec., 1199; 20 Dec., 1306
1958: 3 Jan., 42; 24 Jan., 206; 7 Feb., 299
United Scientific Co., Unitron Instrument Div.
1957: 8 Nov., 986; 22 Nov., 1082; 6 Dec., 1206
1958: 28 Feb., 481; 28 Mar., 712; 25 Apr., 999; 30 May, 1298; 13 June, 1403; 3 Oct., 791

TEMPERATURE CONTROL EQUIPMENT

Blue M Electric Co.
1958: 2 May, 1075
Hallikainen Instruments
1958: 27 June, 1510
Thomas, Arthur H., Co.
1958: 7 Mar., 552
Yellow Springs Instrument Co.
1958: 17 Oct., 909

TENSIOMETERS

National Instrument Laboratories, Inc.
1957: 15 Nov., 1034

THERMOMETERS

Advanced Instruments, Inc.
1957: 25 Oct., 856
Sargent, E. H., & Co.
1958: 18 Apr., 836
Tri-R Instruments
1957: 25 Oct., 874
Yellow Springs Instrument Co., Inc.
1957: 6 Dec., 1199

THERMOSTATS

Brinkmann Instruments, Inc.
1957: 1 Nov., 937; 29 Nov., 1128
1958: 17 Jan., 109

TITRATION EQUIPMENT

Brinkmann Instruments, Inc.
1958: 24 Jan., 199
California Laboratory Equipment Co.
1958: 11 Apr., 823; 9 May, 1123; 6 June, 1354; 4 July, 37; 1 Aug., 264; 5 Sept., 545; 3 Oct., 787
Central Scientific Co.
1957: 25 Oct., 771
1958: 27 June, 1507; 10 Oct., 851
Corning Glass Works
1958: 13 June, 1399; 17 Oct., 911
Laboratory Glass & Instruments Corp.
1958: 25 Apr., 909; 23 May, 1253; 25 July, 170; 12 Sept., 560
Linbro Chemical Co.
1958: 10 Jan., 97; 21 Feb., 427; 14 Mar., 609; 25 Apr., 1009
Palo Laboratory Supplies, Inc.
1958: 7 Mar., 536; 25 Apr., 985
Phipps & Bird, Inc.
1958: 17 Jan., 110; 2 May., 1067; 19 Sept., 675
Sargent, E. H., & Co.
1957: 6 Dec., 1154
1958: 21 Mar., 663; 8 Aug., 273; 3 Oct., 745
Scientific Industries, Inc.
1958: 27 June, 1512
Standard Scientific Supply Corp.
1958: 3 Oct., 788

TRANSDUCERS

Decker Corp.
1958: 24 Jan., 172; 21 Feb., 365; 21 Mar., 619
Sanborn Co.
1958: 14 Feb., 359; 21 Feb., 376; 11 Apr., 780; 9 May, 1084

TRANSPARENCIES

Central Scientific Co.
1957: 13 Dec., 1218
1958: 10 Jan., 103; 21 Feb., 368; 28 Mar., 719; 4 Apr., 723
Polaroid Corp.
1957: 25 Oct., 773

TUBING

Drummond Scientific Co.
1958: 17 Oct., 909
Nalge Co., Inc.
1957: 25 Oct., 864
1958: 14 Mar., 562; 19 Sept., 668

VACUUM DRY BOXES

Blickman, S., Inc.
1958: 21 Feb., 436; 28 Mar., 714; 18 Apr., 889; 23 May, 1255; 20 June, 1458; 18 July, 156; 22 Aug., 424; 19 Sept., 678; 10 Oct., 853
Lennard, P. M., Co., Inc.
1958: 25 Apr., 993

VACUUM EQUIPMENT

Central Scientific Co.
1958: 18 July, 167
Consolidated Electrodynamics Corp., Rochester Div.
1958: 17 Jan., 161; 21 Feb., 429; 7 Mar., 545; 21 Mar., 659; 15 Aug., 369; 19 Sept., 673; 17 Oct., 915
National Research Corp., NRC Equipment Corp.
1957: 1 Nov., 937; 6 Dec., 1211
1958: 3 Jan., 41; 28 Mar., 709; 9 May, 1124; 6 June, 1354; 8 Aug., 313; 5 Sept., 542; 26 Sept., 724; 3 Oct., 787
United Scientific Co., Unitron Instrument Div.
1958: 15 Aug., 331
Welch, W. M., Manufacturing Co.
1958: 1 Aug., 261

VALVES

Phipps & Bird, Inc.
1957: 15 Nov., 1029

VISCOMETERS

Polarad Electronics Corp., Scientific Instruments Div.
1958: 25 Apr., 1000

VOLTAGE STABILIZERS

New York Laboratory Supply Co., Inc.
1958: 25 Apr., 995

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American Instrument Co., Inc.
1958: 20 June, 1451; 15 Aug., 330
Gilson Medical Electronics (GME)
1958: 25 Apr., 993; 23 May, 1257; 6 June, 1347; 4 July, 37; 1 Aug., 259; 12 Sept., 616; 10 Oct., 854
Will Corp., Bronwill Scientific Div.
1958: 14 Feb., 349; 16 May, 1195; 19 Sept., 674; 3 Oct., 784

WARING BLENDORS AND ACCESSORIES

Waring Products Corp.
1958: 21 Feb., 366; 25 Apr., 920
Will Corp., Bronwill Scientific Div.
1958: 18 Apr., 890

WEIGHTS

Ainsworth, Wm., & Sons, Inc.
1958: 18 July, 153; 19 Sept., 669
Gurley, W. & L. E.
1958: 17 Oct., 918
Welch, W. M., Manufacturing Co.
1958: 7 Mar., 532; 4 Apr., 769; 5 Sept., 540

WIRE CUTTERS

Welch, W. M., Manufacturing Co.
1957: 25 Oct., 853

X-RAY EQUIPMENT

Philips Electronics, Inc.
1957: 8 Nov., 950; 22 Nov., 1047; 6 Dec., 1140

ZONE MELTING APPARATUS

Research Specialties Co.
1957: 1 Nov., 935
1958: 13 June, 1401; 29 Aug., 483

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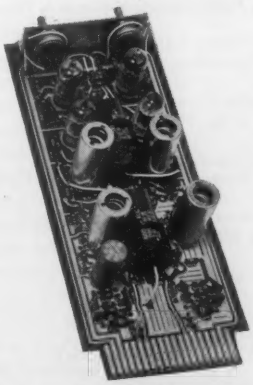

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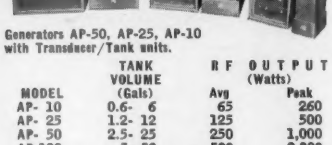

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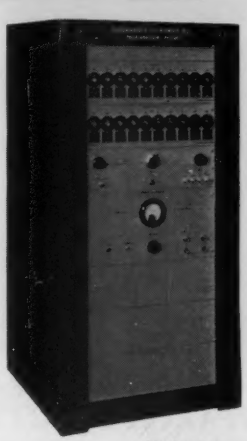

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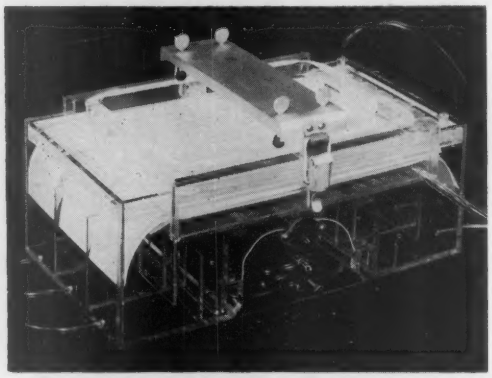

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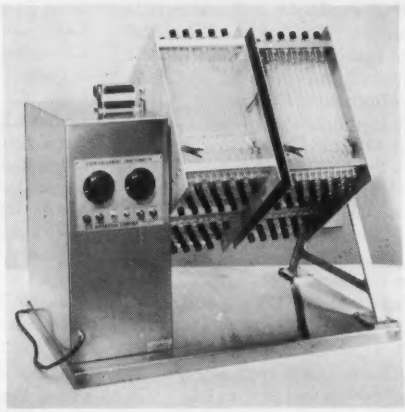

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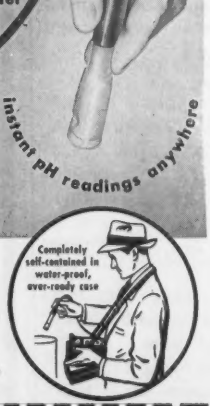

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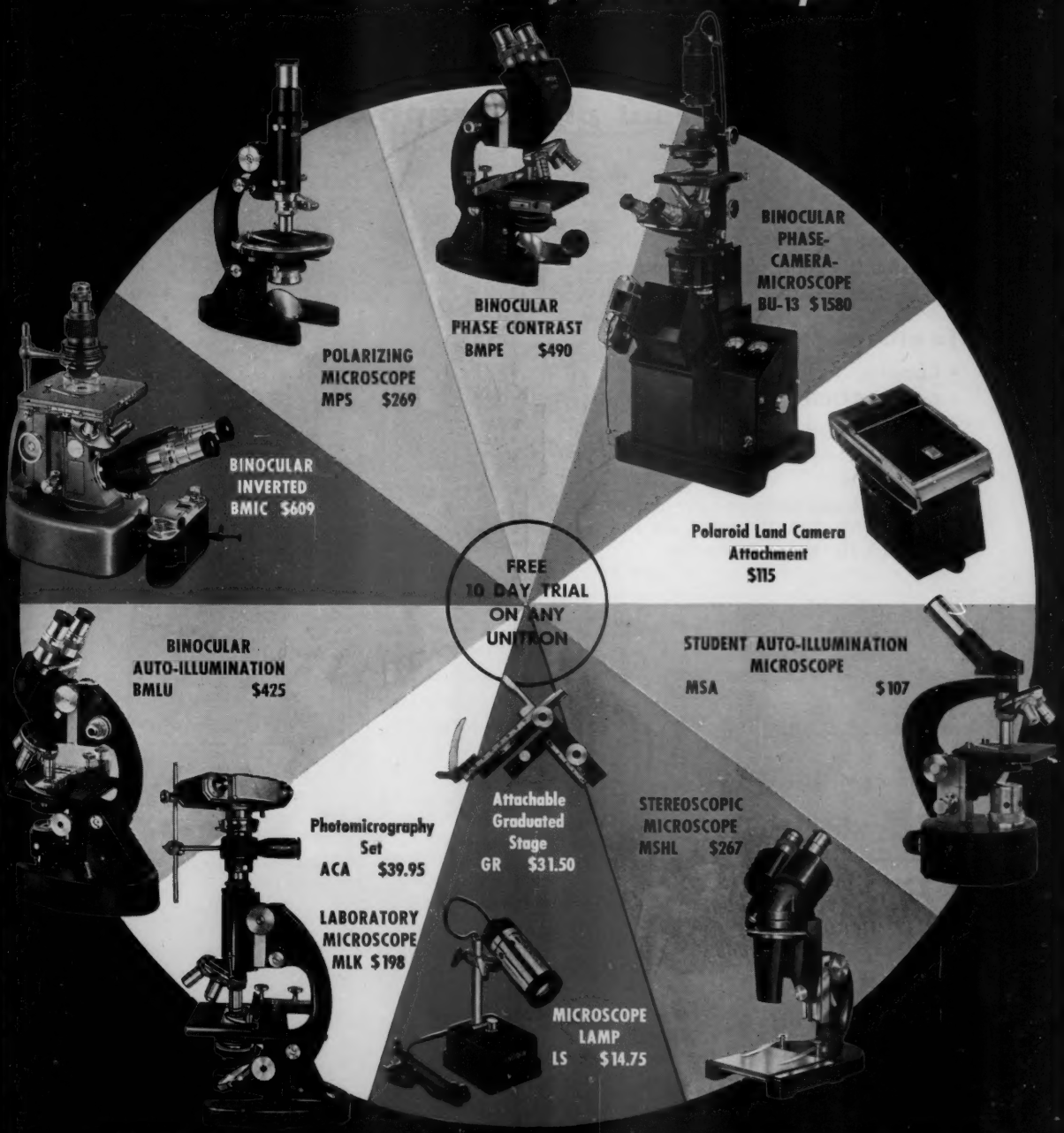
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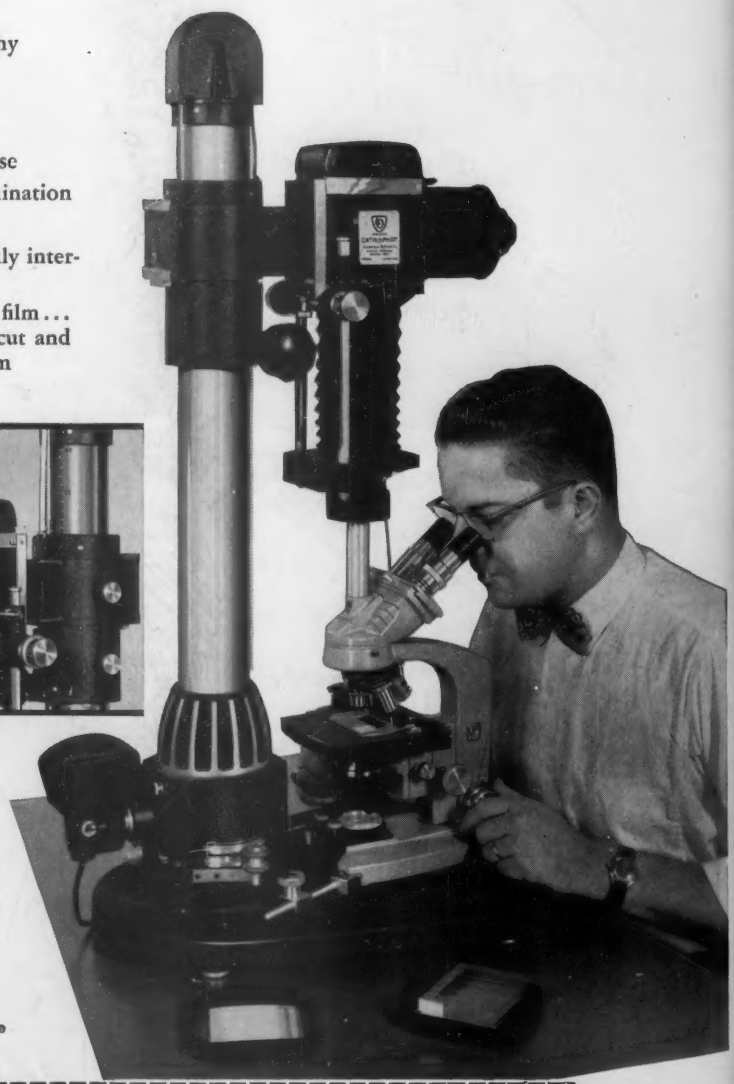

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